SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

ANNUAL CONVENTION NUMBER

Special Features

B.O.D. Determination by Reaeration—Elmore

Viscose Waste Treatment—Eldridge

Waste Sampler—Henderson

Treatment of Ceramic Wastes—Boyd and Watson

Ground Water Pollution by Wastes—Welsch

Sinking Particles in the Sea—Beyer

Twenty-Eighth Annual Meeting—Oct. 10–13, 1955
Ambassador Hotel, Atlantic City, N. J.
(See Page 1102)

SEPTEMBER, 1955—VOL. 27, No. 9

For Effective, Economical Waste and Sewage Treatment, Specify.....

CHICAGO SEWAGE EQUIPMENT

Designed and built especially for sewage and industrial waste treatment, Chicago Sewage Equipment gives you the performance and dependability that only specifically engineered equipment can offer. Years of use in plants all over the country have thoroughly demonstrated the soundness of Chicago operating principles. Constant refinements in design and application by our engineering staff assure you of up-to-date, efficient treatment. There are a few of the reasons why Chicago Sewage Equipment is repeatedly specified by over 95% of active consulting engineers.

VISIT OUR BOOTH at the F. S. I. W. A. Convention, Oct. 10-13, 1955. Ambassador Hotel, Atlantic City, N. J.

CHICAGO PUMP COMPANY
SEWAGE EQUIPMENT DIVISION
111 DIVERSEY PARKWAY • CHICAGO 14, ILLINOIS

BARMINUTORS
Two New Comminution Developments

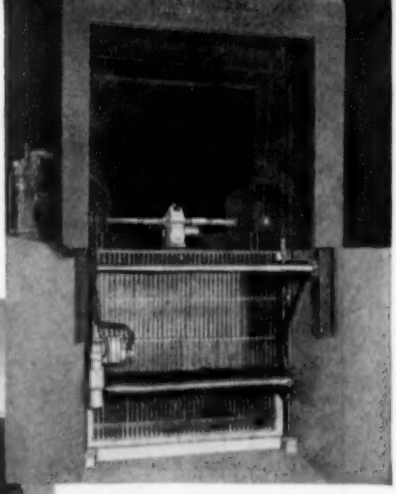
COMMINUTOR
For In-Channel Solids Disposal

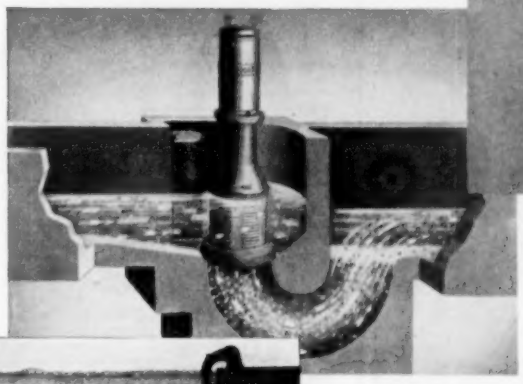
SWING DIFFUSERS
for Continuous, Wide Band Aeration

SCRU-PELLER
Sludge Pumps

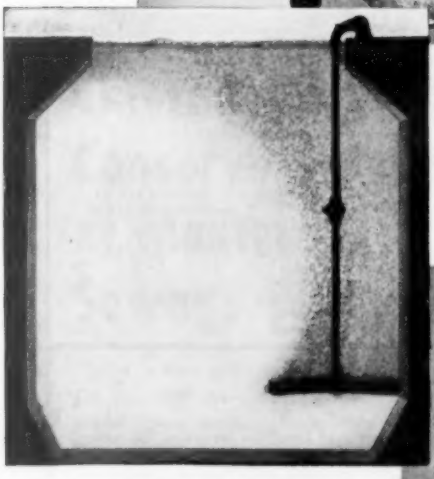
FLUSH-KLEEN SEWAGE EJECTORS
They Can't Clog

Barminutors cut coarse sewage matter into small, settleable solids without removal from the channel. They bring the advantage of COMMINUTION to sewage treatment plants, pumping stations and out-fall sewers regardless of the shape of the influent channel.

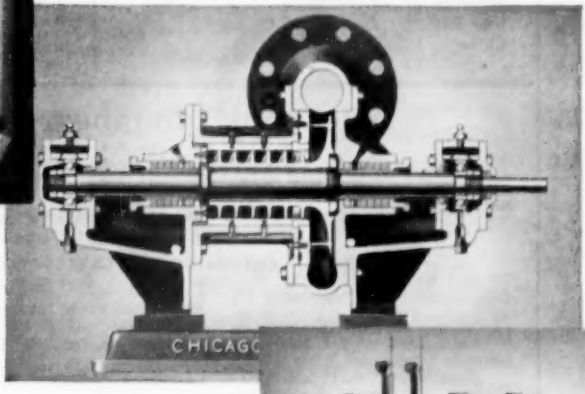




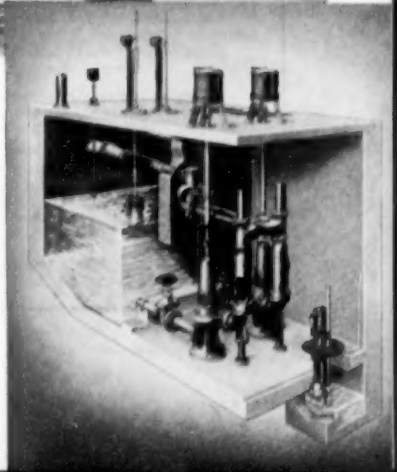
Clean, continuous disposal of coarse sewage — without removal from the channel — is provided by the Comminutor. All coarse material is cut into small, easily settleable solids. 2,500 in service.



Swing Diffusers are the most economical and have the highest aeration capacity of any diffusion system. Simple regulation provides wide flexibility for all kinds of waste and sewage treatment. Individual units easily cleaned without taking tank out of service. 300 installations.



Scru-Pellers chop all coarse and stringy material into small pieces that cannot clog or slow the pump. Simple design assures long life and positive pumping. 8,000 in use.



Flush-Kleen impellers handle only strained sewage. Strainers are backwashed by pump cycle for reliable, clog-proof operation. Over 12,000 in service.

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SEWAGE AND INDUSTRIAL WASTES

REG. U. S. PAT. OFF.

A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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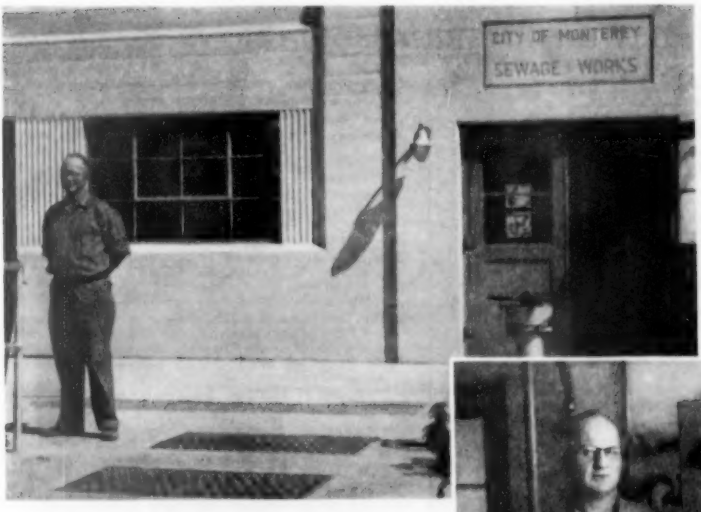

Chlorinizer Conserves Water at Monterey Sewage Works

This is Supt. McCormack of the Monterey, Cal. Sewage Works — standing beside Builders Model DVS-A Automatic-Proportional Chlorinizer. Except for the small dribble of clear water for chlorine control valve pressure, this simple chlorine gas feeder operates entirely on reclaimed sewage effluent, providing an important economy in the plant's operating budget. The rate of chlorine dosage is governed by a Builders Chronoflo Effluent Meter which automatically and accurately proportions the chlorine feed to the effluent flow.

All who have participated in this project — City Engr. Maurice Pearce, Supt. McCormack, and Harry N. Jenks, Consulting Engr. of Palo Alto — are well pleased with the performance of this system. Chlorinizer's ready adaptability to automatic-proportional control, plus its highly efficient performance on a minimum quantity of clear water, are advantages which have really paid off for Monterey.

However you plan to solve your chlorination problem (by manual, flow-proportional, or program control) Chlorinizer has many economies for you. Send today for Chlorinizer Bulletins, to Builders-Providence, Inc., 368 Harris Avenue, Providence 1, Rhode Island.

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Reliable measuring and controlling equipment

VENTURI TUBES—For accurate measurement of sewage, sludge, trade wastes under a wide range of pressures. Flanged, bell or spigot ends in any size . . . any metal.

Cleaning valves at main and throat keep piezometer openings clear. Special short tubes for insertion in existing lines. Type VE elliptical venturi with *flat* top and bottom for low-velocity flows.

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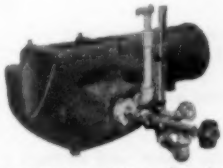

TYPE S PARABOLIC FLUME—Specially designed for measuring sewage and wastes with heavy solids—under low heads! Widely used as indicating device and with Type H Meter for recording and totalizing flow.

Full 20 to 1 flow range with no special approach section. Simple to install. In 6" to 36" standard pipe sizes with flanged, bell or spigot inlet.

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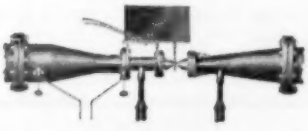

SQUEEZE CONTROLLER—Accurately regulates flow of sewage, sludge, trade wastes. Most accurate primary device, a Simplex venturi tube, has special throat section of *flexible rubber*—measures as it controls!

If flow tends to change, motor-driven clamp adjusts throat . . . quickly returns flow to control point. Viscous flows contact no moving parts in self-scouring throat.

WRITE FOR BROCHURE

TYPE H METER
Gives ±2% accuracy at any point over flow ranges up to 13 to 1. Indicates, records, totalizes. Used with venturi tubes, flumes, weirs for measuring sewage, sludge, trade wastes.

Circular chart gradations evenly spaced for easy reading. Available for wall, panel or floor stand mounting.

WRITE FOR BULLETIN NO. 401

TYPE MO METER—Most accurate inferential type instrument. Measures within ±2% over ranges up to 20 to 1 using venturi tube, flow nozzle or orifice plate. Adaptable to measurement over a 32½ to 1 range.

Evenly spaced rectangular chart is easy to read. Wall, panel or floor stand mounting—for high or low head sewage, sludge.

WRITE FOR BULLETIN NO. 500

OTHER SIMPLEX PRODUCTS

- Remote Transmission for Measurement and Control
- Chemical Feed Units
- Tailor-Made Measurement and Control Equipment
- Flume Liners
- Sewage Type Air Release Valves

Write for Full Details!

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Dept. SI-9, 7 E. Orange Street, Lancaster, Pa.

SIMPLEX®
VALVE AND METER COMPANY

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Association	*Place*	*Time*
Rocky Mountain Sewage and Industrial Wastes Assn.	Connor Hotel, Laramie, Wyo.	Sept. 19–21, 1955
Georgia Water and Sewage Assn.	Georgia Inst. Tech., Atlanta, Ga.	Sept. 21–23, 1955
South Dakota Water and Sewage Works Conf.	Brown Palace Hotel, Mobridge, S. Dak.	Sept. 21–23, 1955
Missouri Water and Sewerage Conf.	Connor Hotel, Joplin, Mo.	Sept. 25–27, 1955
Canadian Institute on Sewage and Sanitation	Schumacher Hotel, S. Porcupine, Ont.	Sept. 28–30, 1955
New England Sewage and Industrial Wastes Assn.	Municipal Auditorium Webster, Mass.	Sept. 29, 1955
Oklahoma Water, Sewage and Industrial Wastes Conf.	Oklahoma A. and M. College Stillwater, Okla.	Oct. 5–6, 1955

TWENTY-EIGHTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations

in conjunction with

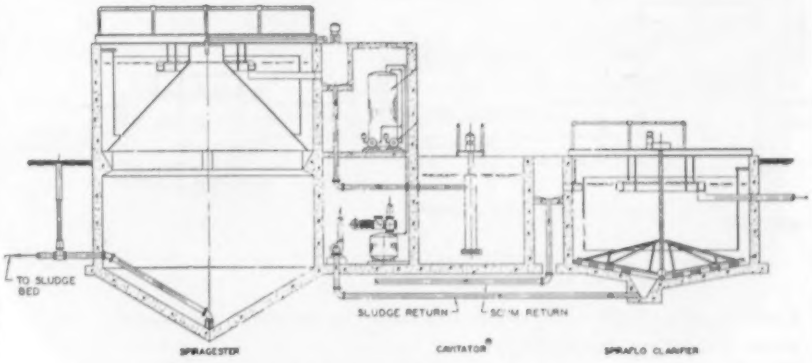
New Jersey Sewage and Industrial Wastes Association

Ambassador Hotel, Atlantic City, New Jersey

October 10–13, 1955

West Virginia Sewage and Industrial Wastes Assn.	Waldo Hotel, Clarksburg, W. Va.	Oct. 19–20, 1955
Pacific Northwest Sewage and Industrial Wastes Assn.	Empress Hotel, Victoria, B.C.	Oct. 27–29, 1955
Nebraska Sewage and Industrial Wastes Assn.	Yancey Hotel Grand Island, Nebr.	Nov. 3–4, 1955
Florida Sewage and Industrial Wastes Assn.	Orange Court Hotel Orlando, Fla.	Nov. 6–9, 1955
North Carolina Sewage and Industrial Wastes Assn.	Robert E. Lee Hotel Winston Salem, N. C.	Nov. 14–16, 1955

For the small activated sludge plant YEOMANS presents THE CAVITATOR.* SYSTEM for Municipal Waste Treatment



One of the many possible arrangements is illustrated. The secondary treatment is provided by the Cavitator mechanism, a specially designed rotor with two arms mounted on a hollow shaft through which air is drawn for dispersion through the tank contents. The arms are streamlined with the outer ends so constructed that when they are passed through the liquid at relatively high speeds they create a zone of cavitation through which the liquid is recirculated continuously. Air and liquid are drawn together creating a vapor pressure condition corresponding to cavitation with its tremendous forces. The oxygen is forced into the sewage and creates countless small air bubbles which permeate the entire liquid body.

—**high oxygen transfer efficiency**—requires only 135 cu. ft. of air per lb. B.O.D. removed per day in the Cavitator System.

—**exceptional performance on relatively low flows** with high B.O.D.

—**low installation and operating cost** with a high degree of purification.

Primary clarification and digestion is accomplished in a single structure, the Spiragester. A Spiraflo is used for final clarification.

Secure detailed information. See your local Yeomans representative listed in the Yellow Pages of your telephone book under "Pumps" or contact factory direct.

See following page for information on YEOMANS Spiragester

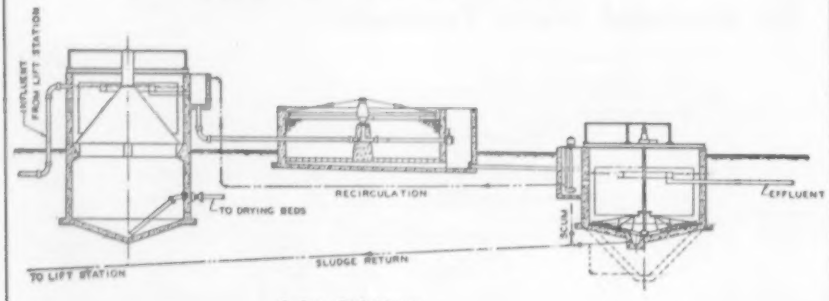
*A YEOMANS Tradename

YEOMANS BROTHERS COMPANY

1999-7 N. Ruby Street, Melrose Park, Illinois

Manufacturers of: Distributors · Clarifiers · Digesters · Mechanical Aerators
Pneumatic Sewage Ejectors · Centrifugal Pumps

For the small trickling filter plant
YEOMANS
SPIRAGESTER



FLOW DIAGRAM

Combination clarifier and sludge digester—for primary and secondary treatment is securing results like these:—

45% Removal of B.O.D.—65% Removal of Suspended Solids—100% Removal of Settleable Solids.

Solids removal is accomplished in the upper portion of the Spiragester by spiral downward flow of the influent, introduced tangentially into an annular race, and enters clarification compartment at bottom. Diffusion is slow, uniform.

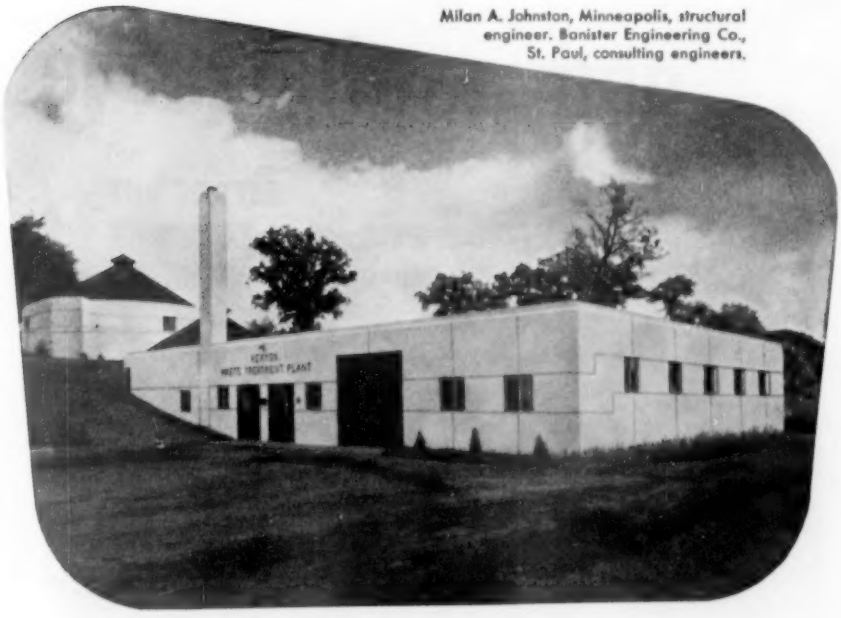
Settled solids in the clarification section enter the digestion compartment, mix actively with digesting material and are attacked by organisms which stabilize the sludge.

In the layout illustrated, secondary treatment is provided by a high capacity trickling filter and final sedimentation by a Spiraflo clarifier.

Ask for Typical Case History Performance Data. See your local Yeomans representative listed in the Yellow Pages of your telephone book under "Pumps," or write factory direct.

YEOMANS BROTHERS COMPANY
1999-7 N. Ruby Street, Melrose Park, Illinois

Manufacturers of: Distributors · Clarifiers · Digesters · Mechanical Aerators
Pneumatic Sewage Ejectors · Centrifugal Pumps



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For a Lifetime of Low-Annual-Cost Service . . .

Architectural Concrete

Architectural concrete is ideal for modern sewage plants—and all other municipal structures. It can be used to create functional yet distinctive buildings like the Sewage Treatment plant in Kenyon, Minn. above. Such structures stand out as symbols of sanitation and good management and are a source of community pride.

Architectural concrete meets structural requirements for strength, durability and firesafety. And it can be molded economically into ornamentation of any style or period.

Architectural concrete is economical too. It is moderate in first cost, costs less to maintain and renders long years of service. These add up to ***low annual cost.***

PORTLAND CEMENT ASSOCIATION

33 W. Grand Ave. / Chicago 10, Ill. / A national organization to improve and extend the uses of portland cement and concrete through scientific research and engineering field work

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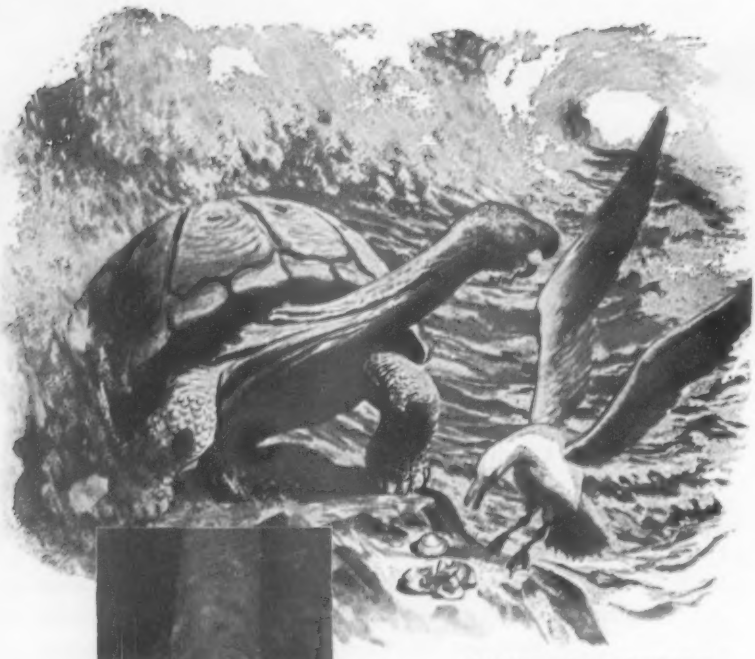


The Galapagos Turtle (or Tortoise) is an inhabitant of the tropics.
It often has a life span of 150 years and weighs up to 500 pounds. Once numerous, its ranks became decimated when man discovered it could live for months without food—making it a good source of fresh meat for sailing vessels, especially whaling ships.

This cast iron water main laid in 1835 by the Bureau of Water of Lancaster is still functioning after 119 years of service.

MODERNIZED **cast iron**

they in common...

THE TURTLE AND CAST IRON PIPE... LONG LIFE!

The Galapagos Turtle frequently lives to be over 100... an outstanding example of longevity in the animal kingdom. In our everyday world, CAST IRON PIPE lives... and serves... for centuries.

AND HERE'S THE PROOF: Listed below are some of the many water utilities still using cast iron pipe that was installed a century or more ago.

DEPARTMENT OF WATER AND WATER SUPPLY, City of Albany, New York
ALEXANDRIA WATER COMPANY, Alexandria, Virginia
BUREAU OF WATER, DEPT. OF PUBLIC WORKS, Baltimore, Maryland
PUBLIC WORKS DEPT., WATER DIVISION, Boston, Massachusetts
DEPARTMENT OF PUBLIC WORKS, DIVISION OF WATER, Buffalo, N. Y.
WATER WORKS DEPARTMENT, Chicago
COLUMBIA WATER COMPANY, Columbia, Pennsylvania
BOARD OF WATER COMMISSIONERS, Detroit, Michigan
CITY OF FREDERICK WATER DEPT., Frederick, Maryland
PUBLIC SERVICE COMMISSION, City of Halifax, N.S., Public Water Supply
WATER BUREAU OF THE METROPOLITAN DISTRICT, Hartford, Connecticut
MUNICIPAL WATER WORKS, Huntsville, Alabama
BUREAU OF WATER, Lancaster, Pennsylvania
CITY OF LYNCHBURG WATER DEPARTMENT, Lynchburg, Virginia
MOBILE WATER WORKS COMPANY, Mobile, Alabama
QUEBEC HYDRO-ELECTRIC COMMISSION, Montreal, Quebec
PUBLIC WORKS DEPT., WATER-WORKS & SEWERAGE DIV., Montreal, Quebec
PENNICHUCK WATER WORKS, Nashua, N. H.
WATERWORKS DEPARTMENT, City of Nashville, Tennessee
DEPT. OF WATER, GAS & ELECTRICITY, New York, New York
DEPT. OF PUBLIC WORKS, BUREAU OF WATER, Philadelphia, Pennsylvania
BUREAU OF WATER, DEPT. OF PUBLIC WORKS, Pittsburgh, Pennsylvania
POTTSVILLE WATER COMPANY, Pottsville, Pennsylvania
BUREAU OF WATER, Reading, Pennsylvania
DEPT. OF PUBLIC UTILITIES (WATER), Richmond, Virginia
DIVISION OF WATER & SEWERS, Sacramento, California
WATER & SEWERAGE DEPARTMENT, City of Saint John, N.B.
DEPT. OF PUBLIC UTILITIES, WATER DIVISION, St. Louis, Missouri
WATER DIVISION, DEPT. OF ENGINEERING, Syracuse, New York
DEPT. OF PUBLIC WORKS, Troy, New York
CITY OF UTICA, BOARD OF WATER SUPPLY, Utica, New York
CITY OF WHEELING WATER DEPT., Wheeling, West Virginia
WILMINGTON WATER DEPT., Wilmington, Delaware
WATER DEPARTMENT, City of Winchester, Virginia
WATER DEPARTMENT, City of Winston-Salem, North Carolina
YORK WATER COMPANY, York, Pennsylvania
WATER DEPARTMENT, City of Zanesville, Ohio

TODAY... modernized cast iron pipe, centrifugally cast, is even tougher, stronger, more uniform. *Where needed and specified,* it is centrifugally lined with cement mortar to assure sustained carrying capacity throughout its long years of service.

On its record, CAST IRON PIPE is the world's most dependable carrier of water.

Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, 122 So. Michigan Avenue, Chicago 3, Ill.

CAST IRON

The G-Clasp stenciled on pipe is the Registered Service Mark of the Cast Iron Pipe Research Association.

pipe FOR MODERN WATER WORKS OPERATION

Rely on REX® When it

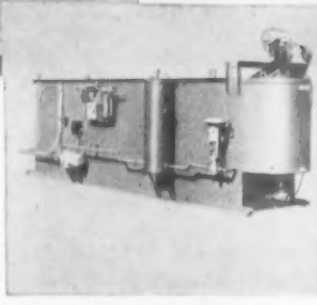
Complete Rex Sanitation Equipment for Trade Waste and Sewage-Water Treatment

CHAIN Belt has the attitude, the aptitude and broad line of equipment enabling them to approach each waste treatment application as a distinct, individual problem. That's why CHAIN Belt is so successful in delivering equipment that will meet the most exacting requirements.

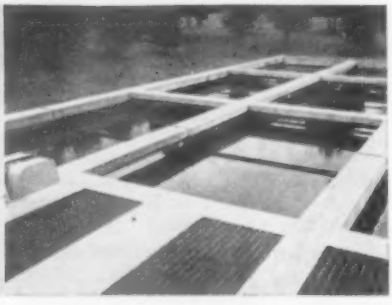
CHAIN Belt can help you with your waste treatment problems. Get in touch with CHAIN Belt Company, 4606 W. Greenfield Ave., Milwaukee 1, Wisconsin, for specific recommendations, helpful drawings and specifications to meet your needs.

Rex Mechanically Cleaned Bar Screens

• CHAIN Belt has a line of products that can help you.



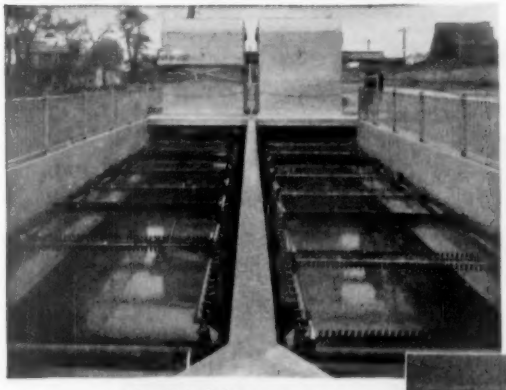
Rex Float-Treat Packaged Unit



Rex Verti-Flo® Clarifiers

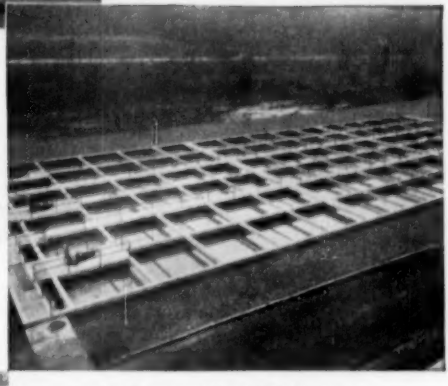
CHAIN BELT COMPANY

Comes to Sanitation Equipment



Rex Grit Collectors

• CHAIN Belt has the practical experience that can help you.



Rex Conveyor Sludge Collectors

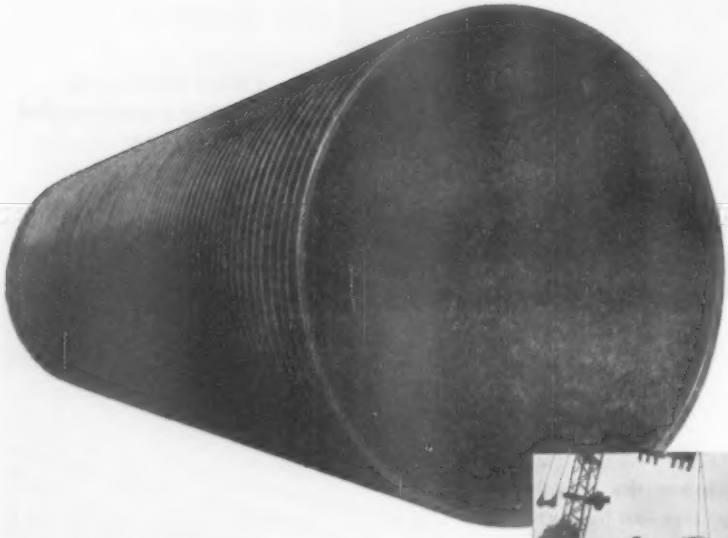
• CHAIN Belt has the engineering knowledge that can help you.

Rex Tow-Bro Sludge Remover

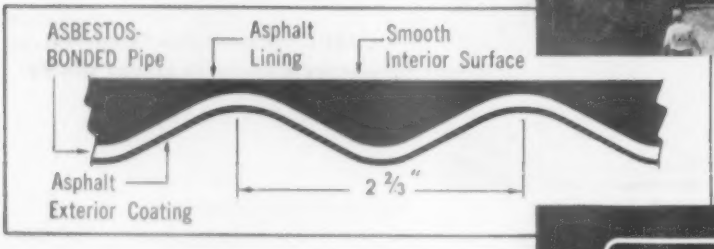
• CHAIN Belt Sanitation Equipment . . . always a leader in proven quality.

district sales offices in all principal cities . . .

Armco announces *New*



Note how the full lining provides a smooth, efficient interior.



ARMCO®

SMOOTH-FLO Sewer Pipe

Combining **TOP FLOW CAPACITY** and **STRENGTH** of Corrugated Metal

Here is a new sewer pipe that meets your needs from every angle—capacity, strength, durability. Armco SMOOTH-FLO Sewer Pipe is efficient to start with and assures continued efficiency throughout the years. It is the result of more than 50 years' experience in developing drainage and construction products.

TOP FLOW CAPACITY

A smooth asphalt lining, centrifugally applied at more than 800 rpm, assures a flow capacity that is equal to or better than any other sewer pipe. This full lining completely fills the valleys of the corrugations. The special grade asphalt, developed by Armco, has been proved in sewer service for the past 30 years. It withstands heat and cold without melting, cracking or spalling and meets the most rugged tests for adhesion and toughness.

STRONG AND DURABLE

To retain continued high flow capacity, any sewer must remain structurally sound —free from failures or malalignment that would impede smooth flow. Armco SMOOTH-FLO Sewer Pipe provides complete assurance on every count.

Flexible Strength

With flexible corrugated metal design, there is no danger of cracking, breaking or crushing under the impact and vibration of heavy live loads.

Strong, Tight Joints

Strong joints plus long lengths with high beam strength mean good alignment year after year. And since joints can't open or separate there is no silting or entrance of ground water to overload sewers or treatment plants.

Durability for Every Service Condition

An overall coating and lining provides ample protection for normal service. Where severe service conditions are encountered in sanitary or industrial sewers you can get the complete protection of Armco ASBESTOS-BONDED.

Ask for Complete Data

These are just the quick highlights. For the complete story applied to your specific problems, just write or telephone us to call the nearest Armco engineer representative. Armco Drainage & Metal Products, Inc., 6135 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation.

WATER, SEWAGE AND TRADE-WASTE TREATING EQUIPMENT

RECTANGULAR CLARIFIERS

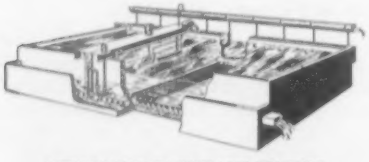
Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. A traveling scraper and skimmer carriage removes settled solids from the tank bottom and scum from the top.

CIRCULAR CLARIFIERS

Hardinge Circular Clarifiers are available in sizes up to 200' diameter, either center-column or beam supported for steel, concrete, wood or tile tanks. Sludge scrapers remove settled solids rapidly through central underflow discharge.

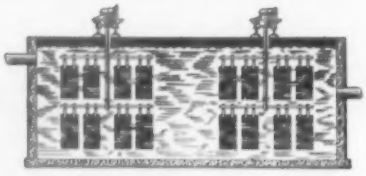
HYDRO-CLASSIFIERS

A large-volume classifier for rapid separation of coarse and fine suspended solids. Frequently used for by-product recovery from waste water.



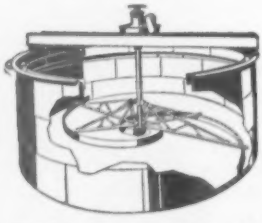
AUTOMATIC BACKWASH FILTERS

For high removal of non-settling or slow settling suspended matter. Self-cleaning sand bed. No shut-down necessary for backwashing. Traveling backwash mechanism.



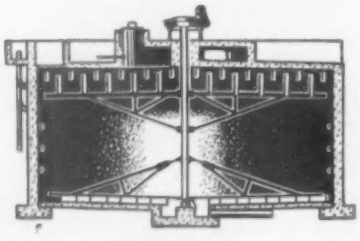
FLOCCULATING UNITS

Slowly rotating paddles on vertical shafts bring the small flocs into contact to form larger masses and hasten precipitation.



"AUTO-RAISE" THICKENERS

For removal of fine suspended solids from supply water, waste water and sewage. "Auto-Raise" mechanism prevents scraper breakage. Manual or power raise supplements "Auto-Raise." Replaceable ring-type ball bearing support for rotating mechanism. Spiral rakes for maximum underflow density.



DIGESTERS

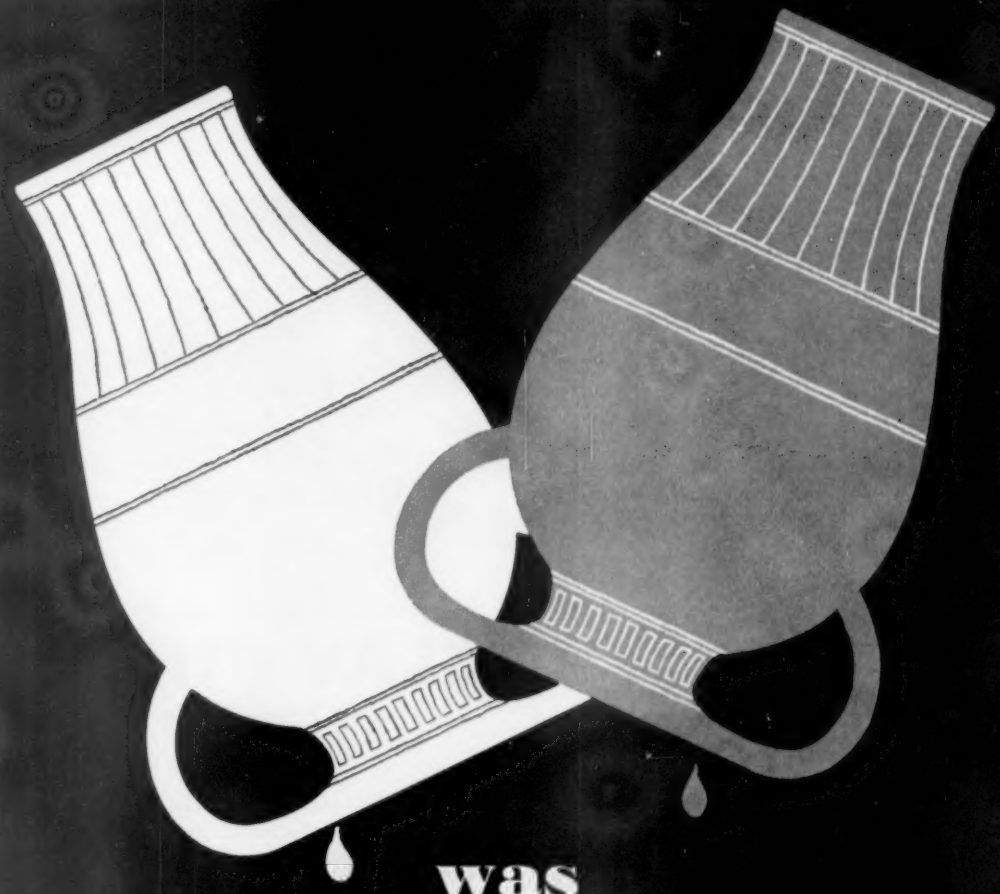
Sludge scrapers and scum breaker arms prevent scum accumulation, insure uniform gas production. Emit a dense digested sludge.

Write for Bulletin 35-D-16

HARDINGE
COMPANY, INCORPORATED

YORK, PENNSYLVANIA · 240 Arch St. · Main Office and Works

New York · Toronto · Chicago · Hibbing · Houston · Salt Lake City · San Francisco



was Rome burned *up!*

Not the city, mind you, for this was before the days of the Nero caper, but the people — they wanted water. Summers were getting hotter and Romans were getting thirstier. They needed something to drink — with or without calories. Thus began the construction of Rome's famous aqueducts, one of which, scarred but faithful, served the city for almost nine hundred years!

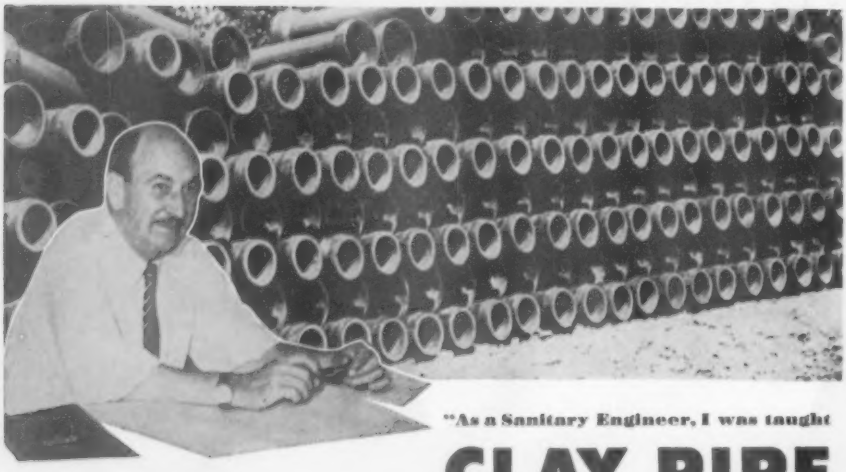
These early aqueduct builders had more to contend with than their thirst. For one thing, they had to carry the ball alone. No skilled specialists or professional consultants stood ready to provide their answers.

Today, carrying the ball alone is almost as defunct as the aqueducts themselves. Experienced consulting, design and operating engineers — each contributing his unique skills — cooperate in solving complex water and waste problems that would have amazed the early Romans.

Graver believes this interrelation is not only useful but desirable and that all involved can not help but profit by it.

GRAVER

GRAVER
WATER
CONDITIONING
CO.



"As a Sanitary Engineer, I was taught

CLAY PIPE

. . . *and I believe in it!*"

— **GILBERT T. JEROME,** *President of George Jerome & Co., Detroit's oldest business firm and one of the oldest engineering organizations in the nation.*

For Michigan's biggest municipal sewerage projects, George Jerome & Co. specifies Vitrified Clay Pipe. The organization, which recently celebrated its 125th anniversary, has designed Clay Pipe sewerage systems totaling hundreds of thousands of feet. Recent municipal projects handled by the Jerome firm include installations at Plymouth City, Flat Rock, Harper Woods, and Livonia.

"I was taught Clay Pipe in school," says Gilbert Jerome. "I'm a sanitary engineer, and I believe in it."

Clay Pipe has *always* been the preferred sewerage material of sanitary engineers the country over. It's completely safe against corrosion by sewer gases or industrial chemical wastes. *And it never wears out!*

CLAY PIPE FITTINGS are available to solve every installation problem. This Long Radius Curve, for example, changes the direction of flow in a line without making an abrupt angle to obstruct the flow.

Vitrified

CLAY PIPE

NATIONAL CLAY PIPE MANUFACTURERS, INC.

1520 18th St. N. W., Washington 6, D. C.

311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio
703 Ninth & Hill Bldg., Los Angeles 15, Calif.
100 N. LaSalle St., Rm. 2100, Chicago 2, Ill.
206 Connally Bldg., Atlanta 3, Ga.

C-855-2A

ONE OF THREE WORTHINGTON PUMPS in new addition to City of Dallas' Cadiz Street pumping station.

Worthington keeps Dallas pumping station a step ahead of city's growth

Fast-growing Dallas has to look ahead to future city expansion when planning improvements in its sewage disposal system.

City engineers kept that in mind when they built the addition to the Cadiz Street pumping station. They provided room for a total of six pumps to handle raw, screened sewage — and installed three Worthingtons. Eventually, they'll install pumps in the three remaining bays, but so far the three Worthingtons have been enough.

Just one example of Worthington service to municipalities everywhere. There's a Worthington unit for your municipal or industrial application — with design and construction proven on the job. Write Worthington Corporation, Public Works Division, Section W.5.2, Harrison, New Jersey.

W.5.2

WORTHINGTON

Visit our suite
Ambassador Hotel
Atlantic City
Sewage and Industrial
Wastes Meeting
October 10 to 13

ALL MAJOR PUBLIC WORKS EQUIPMENT UNDER ONE RESPONSIBILITY

Water Works Pumps • Sewage Pumps • Comminutors • Vertical Turbine Pumps • Vacuum Pump

SCREENS:

EASILY FABRICATED OF EVERDUR FOR EXTRA CORROSION RESISTANCE

Fabricated of Everdur* Copper-Silicon Alloys, this sewage screen offers years of protection against corrosion at all stages of sewage treatment. Everdur alloys are the standard for equipment where high corrosion resistance must be incorporated into readily fabricated, lightweight structures.

Everdur applications include gates, guides and bolts, valve and gate stems, weirs, float chambers, troughs, manhole steps and electrical conduit. These highly corrosion-resistant alloys are characterized by great strength and excellent working properties. Depending on which alloy is used, Everdur may be worked hot or cold, welded, machined, forged or cast and is available in plates, sheets, rods, tubes, electrical conduit and casting ingots.

If you would like detailed information for specific applications or designs, the services of our Technical Department are always available to you. Our Publication E-11 describes Everdur Alloys and applications in detail. Write for it. The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

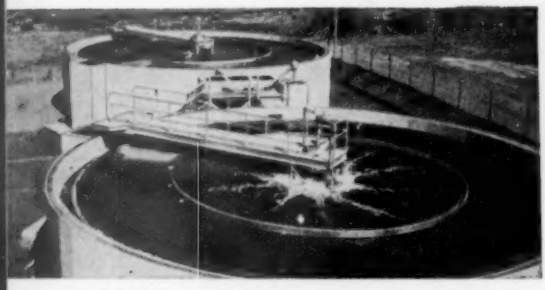
*Reg. U. S. Pat. Off. 53139 A

EVERDUR
ANACONDA®
COPPER-SILICON ALLOYS
STRONG • WELDABLE • WORKABLE
CORROSION-RESISTANT

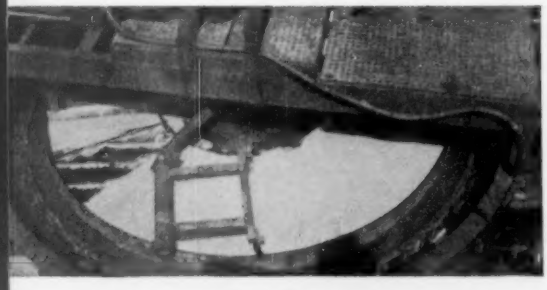
Improvements

in the art of Sewage treatment pioneered by—

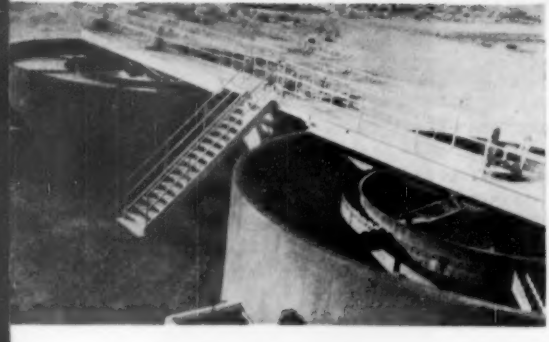
Process Engineers Inc.



● **Oxidators**—A mechanism that combines aeration, flocculation and sedimentation in a single circular tank of desired diameter. Since intermediate treatment results are obtained at almost the cost of primary treatment, very economical clarification is achieved.



● **Flotators**—For industrial and municipal waste treatment when high overflow rates, up to 5000 gallons per sq. ft. per 24 hours, are applicable.



●**Flotator-Clarifiers**—Pressure flotation and sedimentation in a single structure. Solids usually remaining in supension a long time immediately float. Secondary sludge pumped through the pressurizing system into the flotation compartment eliminates the necessity of a sludge thickener prior to digestion or vacuum filtration.

Additional improvements include Grit Separators, Clarifiers, Reactor-Clarifiers, Multi-Clarifiers, Flotator-Thickeners, Rotary Distributors, Cleanable Sight Glasses, Electronic Sludge Thickness Controllers. Removable Sludge Mixers and other developments.

To be sure of getting these improved mechanisms specify Process Engineers and avoid imitations.

Illustrated Booklet #117 gives additional information.

U.S. Patents and Patents Pending.

Process Engineers Incorporated

429 PENINSULAR AVE.
SAN MATEO, CALIF.

666 WASHINGTON ROAD
PITTSBURGH 28, PA.

Harold J. Spaeder
163 Forrest Blvd.
Decatur, Georgia

J. W. Droke & Associates
P. O. Box 2525
Carter Field Station
Fort Worth, Texas

and

P. O. Box 2463
Houston, Texas

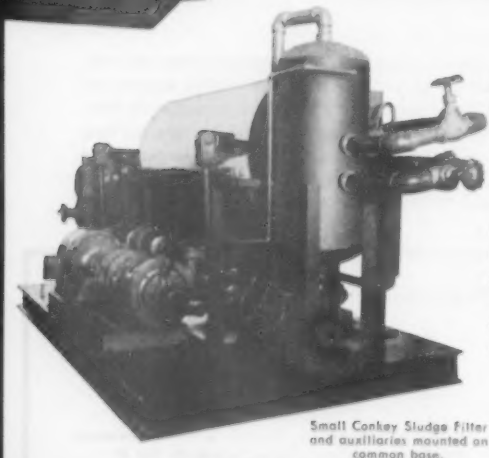
G. A. Fleet Company
P. O. Box 38
North Station
White Plains, New York

Atherholt, Brinton & Glover
529 Brookhurst Ave.
Narberth, Pa.

Compania Marx, S. A.
Apartado Postal No. 1494
Mexico D. F., Mexico

1 or 66

PICK YOUR NUMBER OF FILTERS



Small Conkey Sludge Filter and auxiliaries mounted on common base.

● Conkey Sludge Filters now in use range in size from one filter with auxiliary equipment mounted on a single base (36 square feet of filtering area), to an installation of 66 Rotary Drum Vacuum Filters (38,000 square feet of filtering area), which is the largest rotary type installation ever made for handling sludge.

Municipal and Consulting Engineers have accepted Conkey Sludge Filters as standard dewatering equipment due to their adaptability to successfully dewater many types of sludge and waste.

If you have a sludge or waste disposal problem, write our nearest office and a Conkey Engineer will be happy to work with you.

CHICAGO BRIDGE & IRON COMPANY

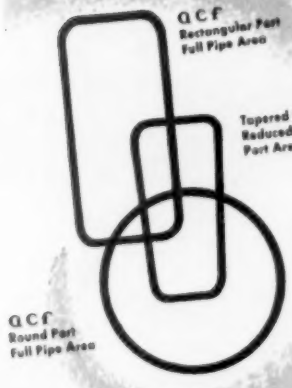
Plants in BIRMINGHAM, CHICAGO, SALT LAKE CITY and GREENVILLE, PA.

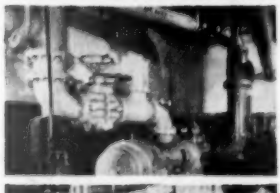
CONKEY EQUIPMENT

Atlanta • Birmingham • Boston • Chicago • Cleveland • Detroit • Houston
Los Angeles • New York • Philadelphia • Pittsburgh • Salt Lake City
San Francisco • Seattle • Tulsa • Washington

BEFORE YOU BUY ANOTHER PLUG VALVE...

COMPARE THE PORT OPENINGS!

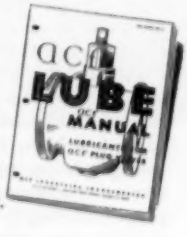




acf Plug Valves are backed up by Proof-of-Performance in every Processing Industry!

Turbulence! Loss of head pressure! These can present real problems when handling slurries and other viscous liquids! And because they are ordinarily the result of valves with "funnel action"... it pays you to make sure that the port opening has the same area as the pipe itself!

Pipe-matching port openings! This is only one of the reasons why more processing engineers than ever before are swinging over to acf Round Port Valves and Rectangular Port Valves. Other features, such as split-second, quarter-turn shut off...specially designed TEFLON* GASKET to prevent head leakage... all add up to lower maintenance costs and fewer work stoppages.



WRITE TODAY for descriptive Catalog E-8, acf Industries, Incorporated, Valve Division, 1501 E. Ferry Avenue, Detroit 11, Michigan.

GET YOUR COPY of the acf Lube Manual, a complete description of lubricants and service recommendations. Ask for Manual No. 3.

*DuPont Tradename

acf CYLINDRICAL FULL PIPE AREA **PLUG VALVES**

City of
SHEBOYGAN WISCONSIN
January 16, 1953
Mr. C.W.Gordon, Manager
Raymond Division
Combustion Engineering Inc.
1315 North Branch St.
Chicago 22, Ill.
Dear Sir:
In reply to your letter of January 14, 1953, regarding the operation of our Flash Dryer System, please be advised as follows;
Our Flash Dryer System was placed in operation in November 1940, and since that time, we have dried all our sewage sludge with this process.
The total expenditures for repair parts during this period, does not exceed $300.00.
We have during this time, disposed of all of the dried product as a fertilizer.
We are well satisfied with the operation of this phase of sewage treatment, and are pleased to show visitors our installation at all times.
Yours very truly,
Supt.

Just mention our name in Sheboygan

Mention it at any rate to Jake Klein, Superintendent of the Sewage Treatment Plant, and he will be glad to show you around. He knows us and our equipment. In fact, for almost ten years the Sheboygan plant has been flash drying its digested sewage sludge with C-E Raymond Flash Drying equipment — and *selling its entire output*. During the past year, the total production of the plant amounted to 905 tons.

Naturally, we're pleased as Punch with Jake's letter reprinted here — but hasten to add we've received many others.

So, if you're thinking of a new disposal plant, investigate the C-E Raymond Flash Drying System. It can incinerate—or dry—or both—alternately or concurrently. We believe we have the best system of sewage sludge disposal. We would like the opportunity to tell you why. B-834-A

COMBUSTION ENGINEERING

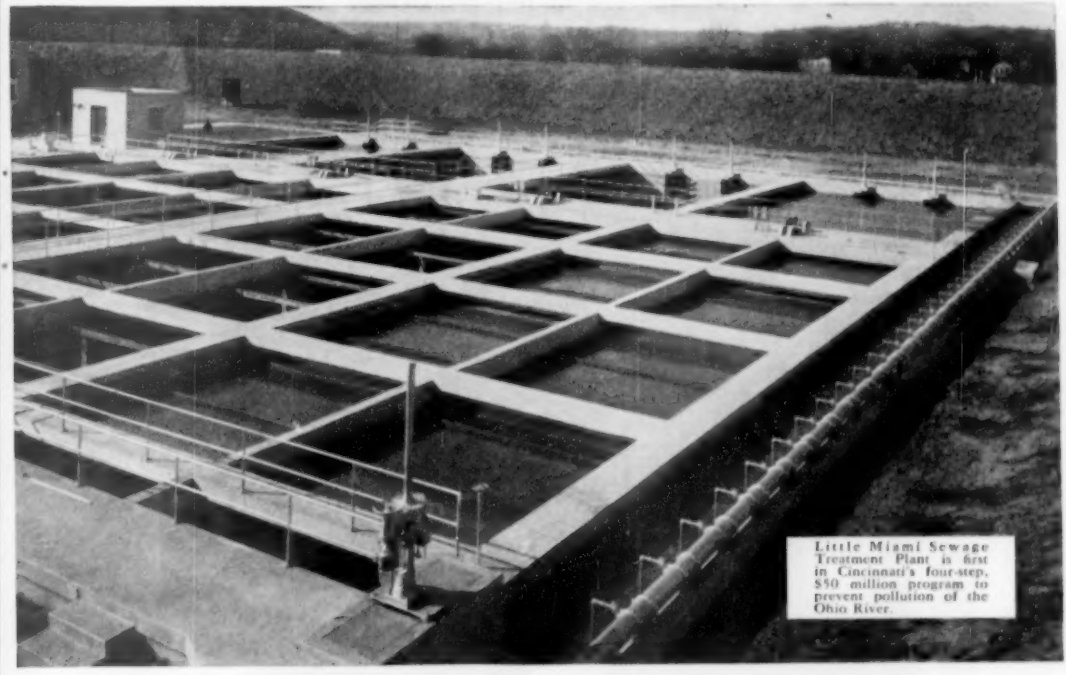
RAYMOND DIVISION

1315 North Branch Street, Chicago 22, Illinois

Eastern Office: 200 Madison Ave., New York 16, N. Y. Western Office: 510 West Sixth St., Los Angeles 14, Calif.

ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

VISIT OUR BOOTHS 14–15—SEWAGE AND INDUSTRIAL WASTES CONVENTION—ATLANTIC CITY, N. J.—OCTOBER 10–13



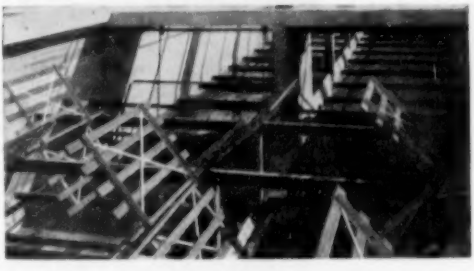
Little Miami Sewage Treatment Plant is first in Cincinnati's four-step, $50 million program to prevent pollution of the Ohio River.

It's LINK-BELT collectors and mixers at Cincinnati's new sewage treatment plant

BECAUSE the 900-mile Ohio River is the water supply as well as waste outlet for many communities in the eight states bordering it, Cincinnati's sewage disposal problems had to be resolved with consideration for downstream cities. Havens and Emerson, Cleveland consulting engineers, chose Link-Belt mixing-settling equipment.

The outcome: a treatment system designed for almost complete removal of settleable solids . . . 45 per cent removal of total suspended solids, estimated at 250 parts per million . . . 65 per cent B.O.D. reduction of raw sewage with 270 parts per million. While present flow is 18 mgd, actual capacity is 29 mgd, expected to be reached about 1980.

In both breadth of equipment line and depth of experience, Link-Belt is well qualified to handle your sewage treatment requirements—be they large or small. Our sanitary engineers will be glad to work with your engineers, chemists and consultants to provide the finest in modern water, sewage or industrial liquids treatment.

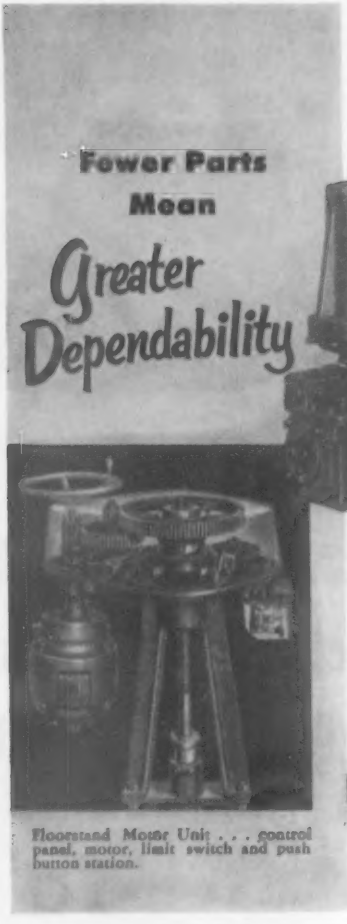


Link-Belt Straightline mixers and collectors in flocculation compartment (foreground) combine to provide maximum solids removal in shortest time. Link-Belt 30 and 48-in. belt conveyors are also used in processing sludge.

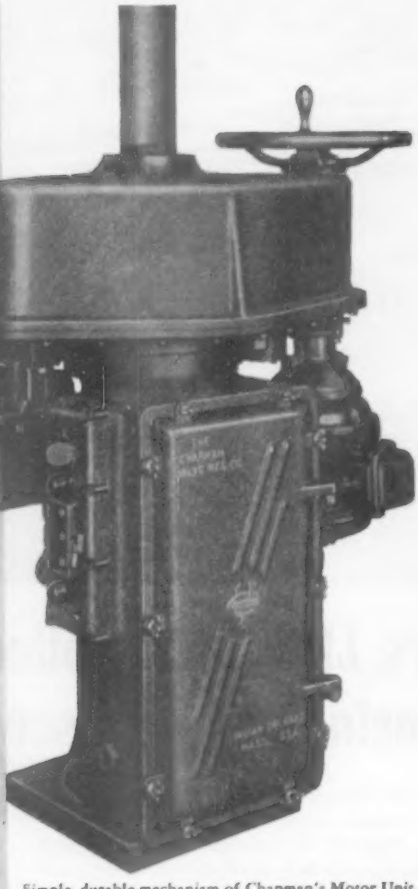
LINK-BELT

SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 13.640



Floorstand Motor Unit . . . control panel, motor, limit switch and push button station.



Simple, durable mechanism of Chapman's Motor Unit. Handwheel remains stationary during motor operation.

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Chapman's simple and rugged Motor Unit gives accurate, trouble-free control of large valves and sluice gates. It has approximately *half as many parts* as any other unit. Its simplified design, low speed motors and low-ratio, stubtooth gears combine to give positive operation without drift, in *any* position and under all conditions.

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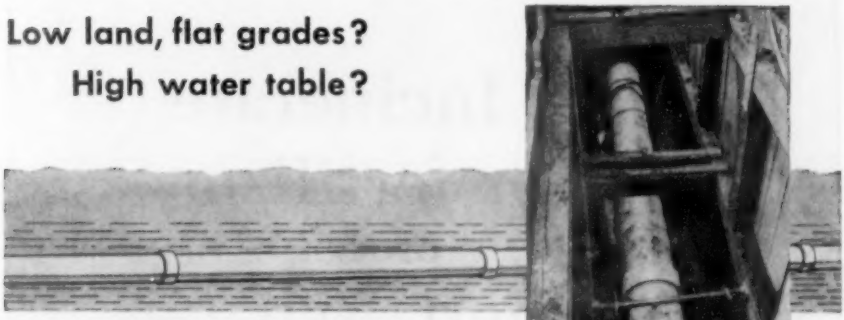
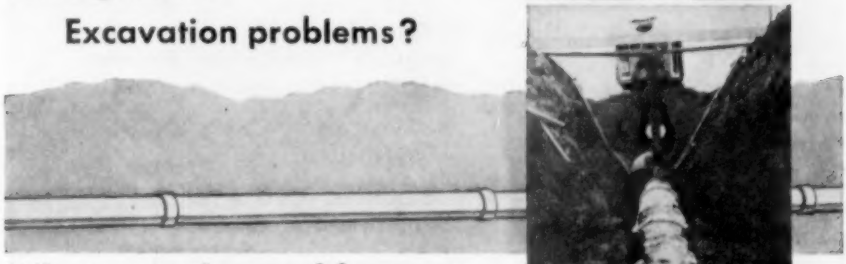
The Chapman Valve Manufacturing Co.

INDIAN ORCHARD, MASSACHUSETTS

Low land, flat grades?
High water table?



Rolling land?
Excavation problems?



Whatever the problem—

Transite® Sewer Pipe

speeds installation, cuts operating costs

In a wide range of conditions, Transite Sewer Pipe and its Ring-Tite® Coupling provide installation and operational *plus-advantages* that add up to important cost savings.

[**Flow Coefficient n-0.010**] For instance, with Transite Sewer Pipe, specified velocity of flow can be attained at a minimum grade. Initial savings may also be reflected in smaller pipe sizes. Its unusually low flow coefficient (n=0.010 derived from the Manning formula) makes this possible. This means less cubic yards of excavation, and may also mean . . . elimination of pumping . . . location of treatment plant at higher elevation . . . lower installation costs especially if in wet or ground-water conditions.

[**Tight Joints**] Where ground water conditions exist (due to a constant water table or during seasonal rains) Transite's Ring-Tite Couplings are *tight* . . . thus treatment-plant dollars are spent to treat *normal* sewage only, not excessive and unnecessary infiltration.

[**Strength**] Made of asbestos and cement, Transite Sewer Pipe is strong and durable. It withstands heavy load stresses, eliminates expensive cradling in many cases. It is available in two strength classifications.

Transite Sewer Pipe is easily handled, quickly assembled and lowered into trench where it adjusts more accurately to line and grade. The Ring-Tite Couplings are easily and quickly pulled, forming tight, flexible joints that *start* tight and *stay* tight.

For your copy of TR-94A, the helpful widely used Sewer Design Flow Chart, based on the Manning formula, write Johns-Manville, Box 60, New York 16, N. Y.

Johns-Manville TRANSITE SEWER PIPE
THE PIPE WITH THE TIGHT JOINTS

Dry or Incinerate . . for fertilizer or Inert Ash

The 1955 Nichols Herreshoff Multiple Hearth units provide unequaled odorless and dustless dual-purpose sludge processing with:

1. The simplest of all incineration operations.
2. The cleanest of all drying methods.
3. The most economical of all dryer-incinerator processes.

Many 1956 features are incorporated in these new projects . . .

Columbus, Ohio—2nd unit.
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Hundreds of older Nichols Herreshoffs installed over the past fifty years prove they stand the test of time!

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Multiple Hearth Dryer-Incinerators

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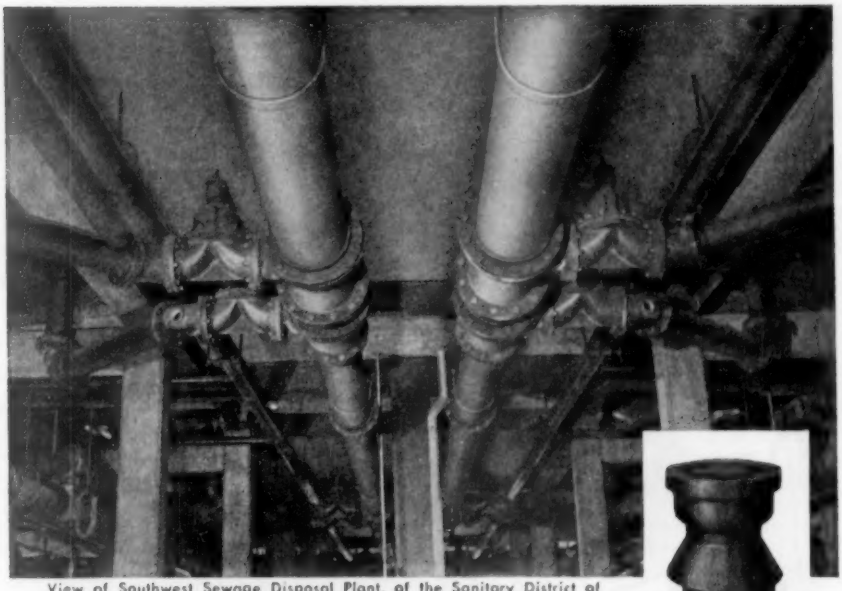

View of Southwest Sewage Disposal Plant, of the Sanitary District of Chicago, Stickney, Illinois . . where Clow Cast Iron Pipe was furnished to meet exact requirements.

Clow cast iron pipe, fittings, valves and specials for sewage plant replacements or new installations

• James B. Clow & Sons with their many years of experience as manufacturers of Cast Iron Pipe and Special Castings for Filtration and Sewage Disposal Plants know the difficult piping problems that continually face the sanitary engineer. Clow shops are completely equipped with the latest machinery. Clow's skilled workmen will produce pipe and specials to your exact specifications. Pipe can be furnished flange and flange, flange and bell, flange and plain end or with mechanical joint and plain end—in sizes 3 through 24 inches in laying lengths up to 18 feet.

CLOW (Threaded) Cast Iron Pipe

Clow also manufactures (threaded) Cast Iron Pipe in steel pipe sizes 3 through 10 inches which has the same outside diameter as common steel pipe. This pipe can be cut, threaded and fitted on the job with ordinary tools of the piping trade.

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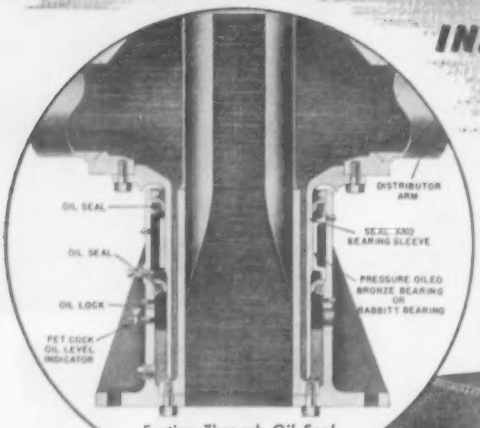

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For helpful data and design details, write for Technical Supplement RD

On exhibit at Annual Convention, Federation of Sewage & Industrial Wastes Associations Atlantic City, Oct. 10-13

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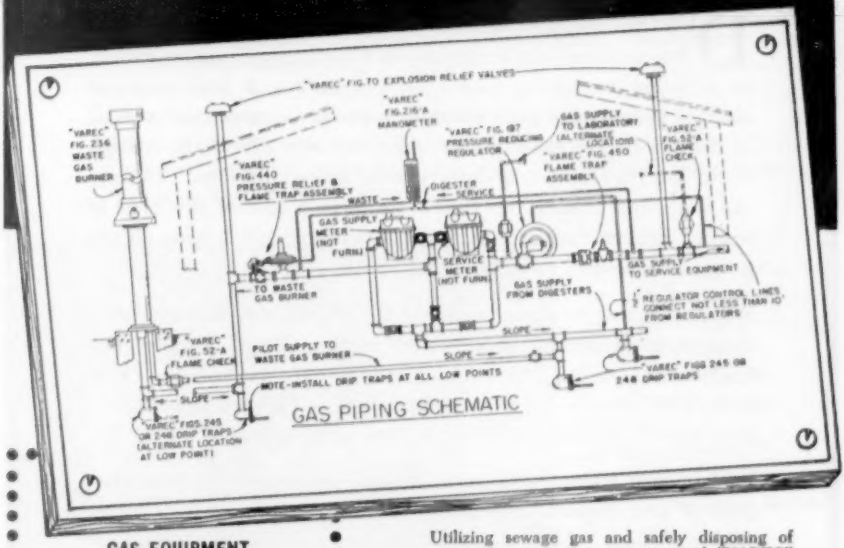
"VAREC" FIG. TO EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 87 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATION)
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 52-A FLAME CHECK
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
DIGESTER
WASTE
SERVICE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES CONNECT NOT LESS THAN 10' FROM REGULATORS
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
"VAREC" FIGS. 245 OR 248 DRIP TRAPS
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
SLOPE
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)

GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

PRESSURE RELIEF AND FLAME TRAP ASSEMBLY
"VAREC" Fig. No. 440

FLAME TRAP ASSEMBLY
"VAREC" Fig. No. 450

FLAME CHECK
"VAREC" Fig. No. 52A

EXPLOSION RELIEF VALVES
"VAREC" Fig. No. 70-1

WASTE GAS BURNER
"VAREC" Fig. No. 236

DRIP TRAPS
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

MANOMETERS
"VAREC" Fig. No. 216A

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Utilizing sewage gas and safely disposing of excess gas is an automatic operation with "VAREC" Equipment incorporated into your sewage plant design. With this equipment, accurate gas pressures are maintained in all service lines. As soon as the digesters make more gas than required for service, the pressure relief valve to the waste gas burner opens to permit safe burning of the excess.

Flame flashback to valuable equipment is prevented with "VAREC" Flame Traps and Flame Checks. The flame arresting element of the Flame Trap is designed to eliminate flame propagation of even more inflammable gases than encountered in sewage service. This element is the same as that used in "VAREC" Flame Arresters listed by the UNDERWRITERS' LABORATORIES for petroleum product storage.

Emergency explosion relief is accomplished with "VAREC" Explosion Relief Valves. These valves should be installed outside of any buildings.

An enlarged engineering drawing of the above gas piping detail will be sent upon request. If you design sewage treatment plants, write today.

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Our Present Position, and Future Goals

DURING the past several years, much of our pioneer work has matured into reality as our Coilfilters go into operation. In addition to having successful operations, it has been our thought to maintain close relations with the Contractors involved in the building of these plants, the Engineers who do the design work, and the Operators who live with the installations. Despite the trials and tribulations that seem to be a part of this type of work, I believe that we have gained many friends among all the people involved in these projects.

With reference to sludge dewatering technology, we can see a distinct trend toward the direct dewatering of raw sludge on our Coilfilters. On installations operating to date we have been able to find an answer for the odor problem. This, of course, is a large factor, in addition to the economics involved.

With regard to the future, we believe that research, both theoretical and applied, is indicated on the fundamentals of solids agglomeration. We have been fortunate in being able to set up an organization with facilities to do work along these lines.

In perspective, we believe that a splendid job has been done in the past five years on sanitary installations in this country, and are indeed gratified to be accorded a place in this work. Currently our proportion of total sludge dewatering installations is very impressive and we intend to maintain our position through continued service to the Engineers, Contractors, and Operators.

Respectfully,
T. R. Komline

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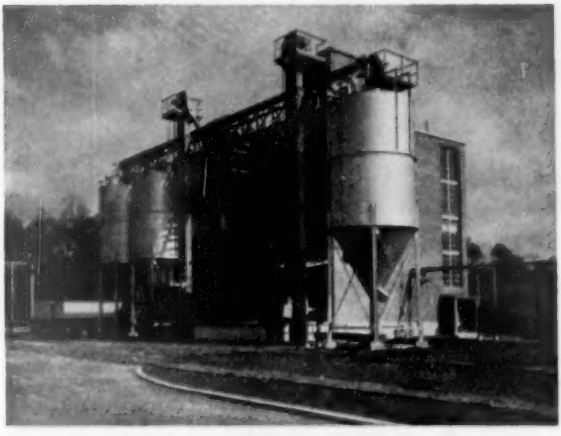

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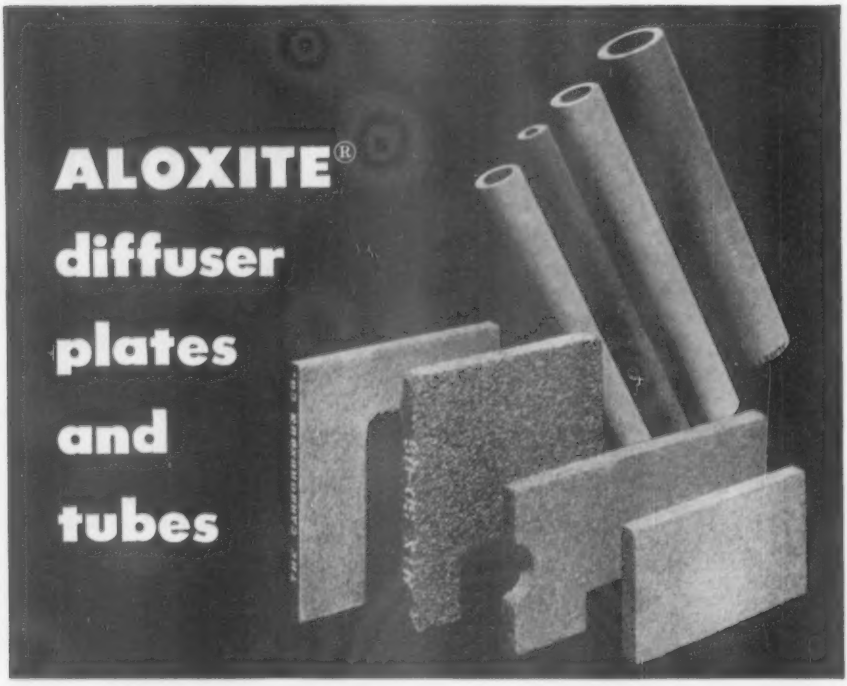

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When considering air diffusers, these facts are worth keeping in mind: Of the many aeration methods and materials tried since the discovery of the activated sludge process (in 1915), *only one* has stood the test of time. Only porous ceramic diffusers have been used with continued success. And more installations have been made with ALOXITE aluminum oxide diffusers than all makes combined. Hundreds are still operating — many after over 20 years' service.

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ALOXITE diffusers are available in plate or tube form, and in a full variety of grades. This permits maximum flexibility of design. It also lets you select the exact grade for optimum diffusion, (consistent with air supply quality, pressure loss characteristics, and overall life). This is particularly important since the introduction of the oxygen absorption test.

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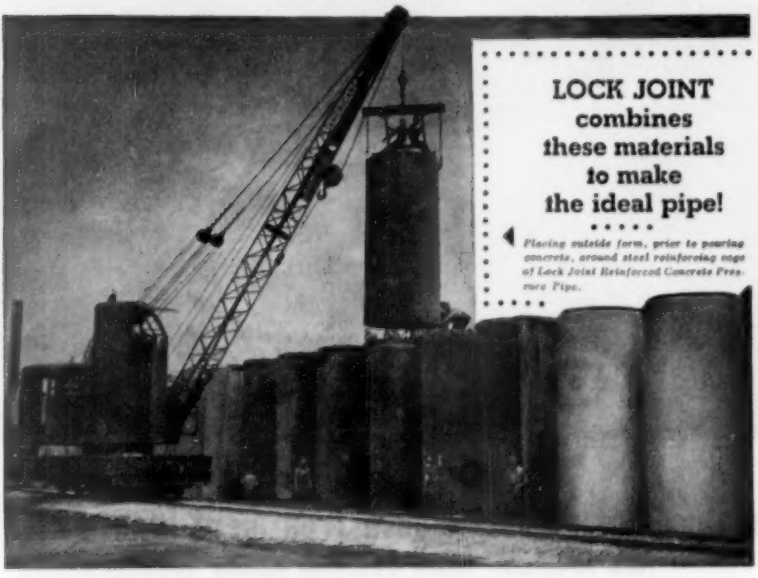
There's no substitute for CONCRETE and STEEL!



LOCK JOINT combines these materials to make the ideal pipe!

Placing outside form, prior to pouring concrete, around steel reinforcing cage of Lock Joint Reinforced Concrete Pressure Pipe.

CONCRETE, with its proven qualities of durability, non-corrosion, resistance to electrolytic action, and high compression strength is combined, by Lock Joint, with steel's toughness, resilience and high tensile strength to make a pipe that retains the best qualities of both—non tuberculance, high structural strength and long life with little or no maintenance. Dense concrete affords complete protection for the quality reinforcing steel. Both materials are carefully calculated to meet your pressure needs with a wide factor of safety. The Lock Joint Pipe Company's Rubber and Steel Joint is extremely watertight and, at the same time, flexible.

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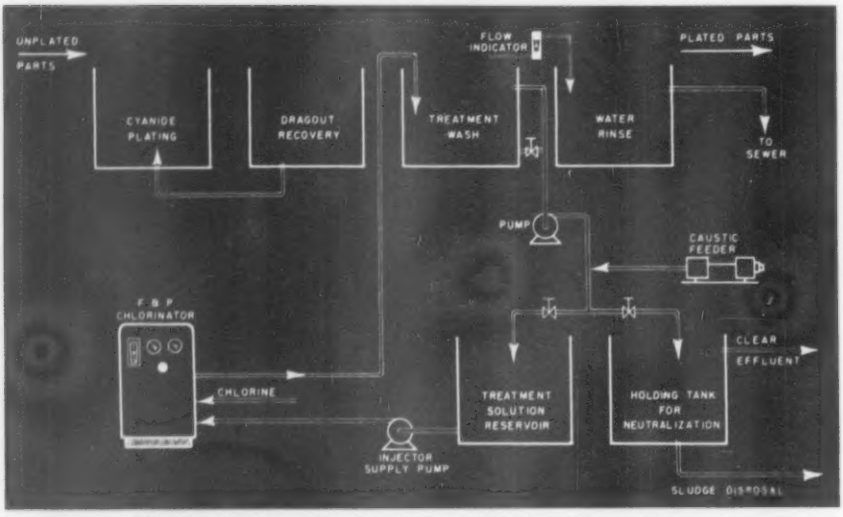
FP *complete process instrumentation*



Schematic flow diagram illustrates an Integrated Waste Treatment System.

Cut Costs of Plating Waste Treatment Plants by 75%

New Integrated Waste Treatment System* provides answer to waste disposal problems

An F&P Chlorinator in integrated system for cyanide waste treatment at Metals Protection Co., Punxsutawney, Pa.

**Pat. applied for*

Conventional treatment systems often present a major economic problem to the plating operation because of the large financial investment required for equipment. To overcome this, Dr. Leslie Lancy, an electroplating specialist and consultant, devised the Integrated Waste Treatment System.

In addition to a 75% saving over other forms of plating waste treatment, this process provides simplicity and reliability of operation, with freedom from maintenance. Use of F&P Chlorinators and Sulfonators enabled Dr. Lancy to achieve these essential factors—plus low initial cost.

These are the advantages of the system:

- Low initial cost
- No settling basins needed
- Ties in with plating line without disrupting production
- Treats waste at source
- Product quality maintained
- Adaptable to any type of plating waste problem

Write for copy of "Instrumentation for Control of Cyanide and Chrome Waste Treatment Processes."

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Centralized control systems
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A glance at this pipe gallery in an Ohio sewage treatment plant tells you that these *could not be* all standard fittings.

Here, as with many other sewage, water treatment, and industrial installations, the engineer, contractor, and job superintendent were assisted by the long-experienced engineers of the American Cast Iron Pipe Company.

"Specials" are a specialty at the American Cast Iron Pipe Company. At American, each special casting is "custom-made," to your design and specifications, in the nation's largest and most complete wood and metal pattern shops and fittings foundries.

Call on the experience, skill and facilities of the American Cast Iron Pipe Company when you plan your next piping installation. Highly-trained engineers will 'take off' lists of materials and submit complete prices on centrifugally cast pipe with standard and special fittings. Inquiries invited.

50th ANNIVERSARY ACIPCO 1905 1955

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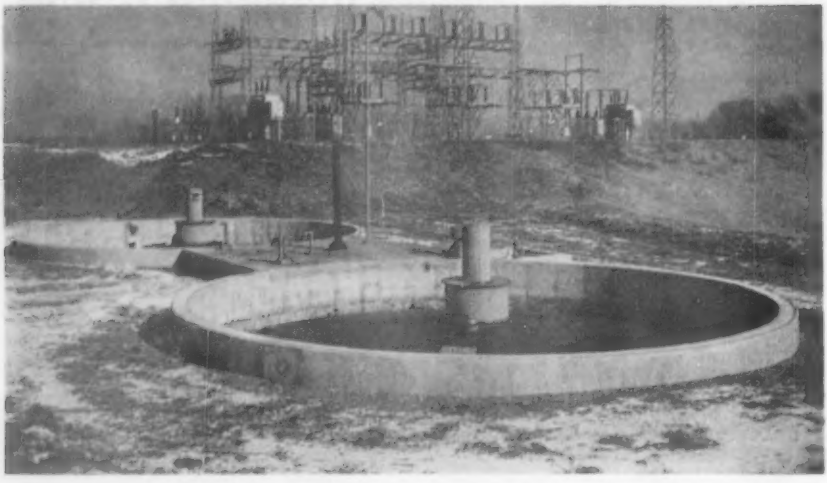
AMERICAN
CAST IRON PIPE COMPANY
BIRMINGHAM ALABAMA

Two PFT Floating Covers on the 40', underground digesters.

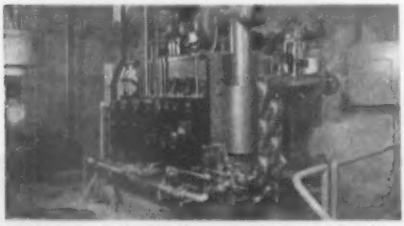


New Eli Lilly plant treats its own wastes

WITH MODERN PFT EQUIPMENT

Completed in 1954, Eli Lilly's modern pharmaceutical plant at Lafayette, Indiana contains a complete waste treatment system for its antibiotic broth wastes, process wash, floor wash and sanitary wastes. An integral part of this highly flexible plant is the PFT "Controlled Digestion" system with provision for direct discharge of the concentrated antibiotic waste to the digesters.

A PFT Floating Cover is installed in each of the two 40' diameter digesters. Floating Covers accelerate digestion and provide positive scum submergence while actually simplifying operations. Because no fixed levels need be maintained, additions and withdrawals can be made at times best suited to the overall operation. Near the covers, a *PFT Waste Gas Burner* burns excess gas and avoids odor nuisance.



PFT Heater & Heat Exchanger in the Control Building.

In the underground Control Room, a *PFT Heater & Heat Exchanger* unit maintains close temperature control in the digesters *automatically*. Fired by gas *or* oil, the unit cuts fuel costs by utilizing all gas produced in the digesters.

Also in the Control Room are two *PFT Supernatant Liquor Selectors* (with Gauge, Sight Glass & Sampler) and a complete set of *PFT Gas Safety Equipment.*

The PFT Kraus nitrification process is included to assure proper functioning of the trickling filter system with waste which may be deficient in nitrogen.

PFT assisted consulting engineers by showing the adaptability of its processes and equipment in meeting the specific waste treatment requirements of this plant. To further assure successful treatment, PFT instructed plant personnel in the proper operation of its equipment.

Design of plant by / *H. K. Ferguson Co. Cleveland, Ohio*

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waste treatment equipment exclusively since 1893

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 27 **September, 1955** **Number 9**

Contents

Sewage Works

Determination of B.O.D. by a Reaeration Technique. By Harold L. Elmore 993

Interceptor and Sewage Treatment Program at Knoxville, Tennessee. By Leonard C. Bailey 1003

Mechanics of Oxygen Absorption in Spiral Flow Aeration Tanks. II. Experimental Work. By Henry R. King 1007

Industrial Wastes

Treatment of Wastes from Viscose Processes. By W. J. Eldridge 1027

Treatment of Lithographic Wastes. By John J. Baffa and Harold E. Orford .. 1032

Sewage and Industrial Waste Sampler. By W. B. Henderson 1036

Biochemical Oxygen Demand of Pure Organic Compounds. By H. Heukelekian and M. C. Rand 1040

Ceramic Waste Treatment. By G. M. Boyd and K. S. Watson 1054

Suggested Procedure for Evaluation of Biological Oxidation of Organic Chemicals. By E. J. Mills, Jr. and Vernon T. Stack, Jr. 1061

Stream Pollution

Ground Water Pollution from Industrial Wastes. By W. Fred Welsch 1065

Discussion By Maxim Lieber 1069

The Spreading of Sinking Particles in the Sea. By Fredrik Beyer 1073

The Operator's Corner

Something to Think About 1079

Let the People Know 1079

The Responsibility of the Administrator and Operator. By Eric V. Quartly 1080

Lift Station and Grit Chamber Forum 1082

Personal Liability of Public Employees Engaged in Governmental Functions. By John R. Nimocks 1088

Interesting Extracts from Operation Reports: Detroit, Mich. 1093

The Use of Manual of Practice No. 3 1097

Restaurant Grease Interceptor 1098

Tips and Quips 1100

Federation Affairs

Twenty-Eighth Annual Meeting Preview 1102

Charles Alvin Emerson—In Memoriam 1109

Reviews and Abstracts 1110

Proceedings of Member Associations

Arizona Sewage and Water Works Association 386a

Louisiana Conference on Water Supply and Sewerage 388a

California Sewage and Industrial Wastes Association 390a

Index to Advertisers 405a

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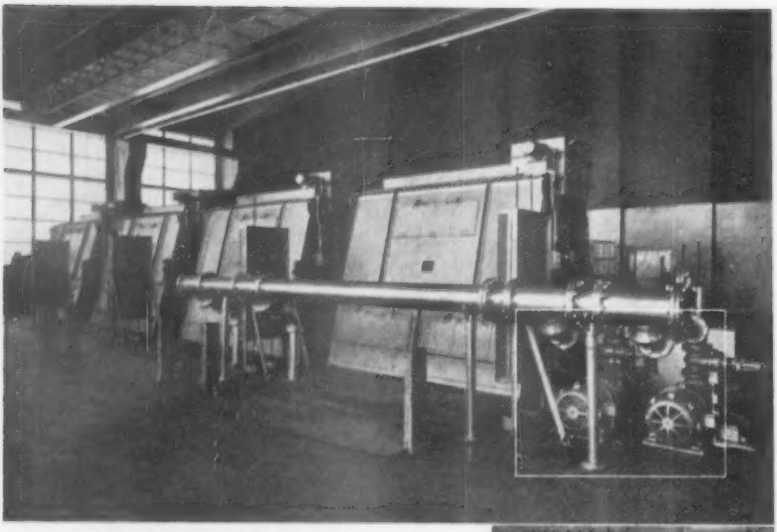

General view of screen room at Hyperion with Type S Screens at left and Disintegrators at right.

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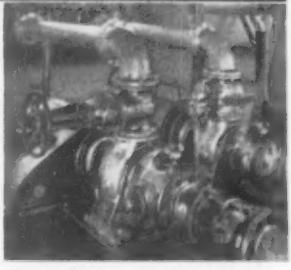

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Sewage Works

DETERMINATION OF B.O.D. BY A REAERATION TECHNIQUE *

By Harold L. Elmore

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A great variety of papers related to the determination of biochemical oxygen demand have been published in recent years. These papers have been concerned primarily with modification of the standard dilution technique and the development of new B.O.D. techniques for application to concentrated industrial wastes and sewage samples. In contrast, few papers have appeared concerning the development of modified techniques to more closely relate the B.O.D. determination to the natural conditions prevailing in the receiving waters.

The determination of B.O.D. for use in the study of surface water quality differs in several ways from the same test used to measure the efficiency of sewage and industrial waste treatment plants. The concentration of B.O.D. in stream samples is in a much lower range. Natural seeding material is available in the stream which is often especially adapted to assimilate a specific pollutant. Minerals and nutrients available in streams are extremely variable and are dependent on innumerable factors. Suppression of the nitrogenous phase of B.O.D. is often resorted to in measuring the efficiency of sewage treatment plants, but in stream samples it is essential that both carbonaceous and nitrogenous phases be given full representation.

It is not surprising that a B.O.D. value derived from a sample that has been neutralized, buffered, detoxified, and diluted with a solution of minerals and nutrients often does not give much indication of downstream conditions. A more useful parameter would result if the data obtained from B.O.D. determinations could be applied directly to stream conditions. This objective can be approached by incubation of B.O.D. samples under conditions related as closely as possible to those in the stream at the point under study. In the final analysis, the ideal measure of pollution is a true representation of the effect of the effluent on the receiving water. It is felt the reaeration technique represents considerable progress toward this goal.

When changes in water quality are to be studied in streams and reservoirs, it often becomes desirable to measure biochemical oxygen demand for much longer than the standard 5-day period. If the B.O.D. of a sample is determined repeatedly at daily intervals and these values plotted against time, a curve will result that defines the history of oxidation of the sample. These long-term B.O.D. curves can be useful in many ways.

When an effluent contains a high concentration of nitrogenous compounds, the standard 5-day B.O.D. test will not reflect the true effect of this effluent on the receiving water. Figure 1 shows a group of long-term B.O.D. curves where this is the case.

* Presented at 1954 Annual Meeting, Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.; Nashville, Tenn.; Sept. 20–22, 1954.

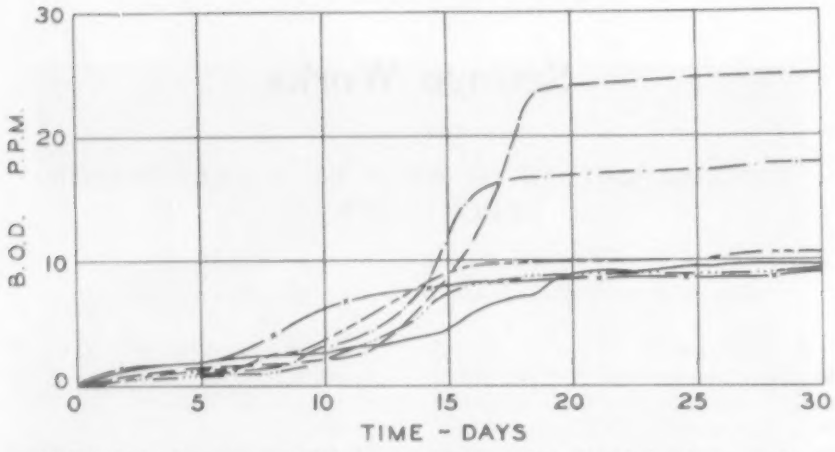

FIGURE 1.—Long-term B.O.D. curves showing effect of variation in ammonia nitrogen concentration.

No relationship exists between the 5-day and the ultimate B.O.D. demand, the former being mainly the carbonaceous demand.

Water samples containing bacteriostatic agents often will exert negligible B.O.D. in five days. However, when these agents are decomposable, or are complexed with suspended matter to take on a nontoxic form, the long-term B.O.D. will define more clearly the effects to be expected downstream.

An interesting use of this type of data is the prediction of dissolved oxygen content of the effluent from reservoirs. This can be done in some cases where thermal stratification and density underflows are present and the long-term demand is known for the streams tributary to the reservoirs.

Dilution Technique Factors

The reaeration technique presents a convenient and precise method for deriving these long-term B.O.D. curves. In contrast, many difficulties arise when the dilution technique is used for this purpose. Some of the difficulties inherent in the use of the dilution technique to obtain either a long-term or a 5-day B.O.D. involves the following:

Dilution Water:—When samples must be diluted to prevent total oxygen depletion, within the incubated sample, the water used for this dilution presents many problems. The standard fortified Formula C water contains minerals and nutrients that may or may not represent conditions present in the body of water under study (1).

Seeding:—A variety of seeding materials has been suggested for the dilution water. Fresh settled sewage (2), stale settled sewage (3), polluted river water (4), and river water well below the source of pollution (5), have been suggested by various workers in the field. Even in the case of settled sewage the work of Sawyer, Callejas, and Moore (6) points out the divergence in results that can be expected unless a source is carefully selected and tested. Seeding is a complex and often troublesome feature of the dilution technique.

Selection of Dilutions:—The analyst is often faced with a problem in the selection of the proper dilution or dilutions to use. If the oxygen demand is underestimated, complete depletion occurs in the incubated sample and results are not obtained. When

the demand is overestimated the results are inaccurate due to the minute variation between the initial and final titration. Should the analyst "play it safe" and use numerous dilutions, the expenditure in time is increased many-fold. In any event, the results obtained are often satisfactory or unsatisfactory strictly by chance, as all the factors involved cannot be made available to the analyst at the time the dilutions must be selected.

Blank:—When dilution water is used, and more particularly seeded dilution water, it is necessary to carry a blank along with the determination. The value of the B.O.D. in the diluted sample is corrected by the amount indicated by the blank. Since the total demand of the blank will seldom exceed 1 p.p.m., the errors from each determination will be large as compared to the total B.O.D. of the blank. Then, too, the scatter of daily values due to slightly varying rates in the different bottles will frequently cause difficulty in assessing the blank correction. In the later phases of a long-term B.O.D. the application of the blank correction will often cause inversions in the B.O.D. curve and bring on difficulties of interpretation.

Sliding Scale of Results:—When several dilutions are completed on the same sample and the B.O.D. curves are plotted after correction for dilution and blank, normally a family of curves is obtained with the more dilute samples indicating a higher value. This basic discrepancy has been attributed variously to toxicity of the samples (7), inhibition of nitrite formation below 2 p.p.m. dissolved oxygen (16), variations of rate of B.O.D. with concentration of dissolved oxygen available (1), and most recently to small errors in determination of the proper blank (8). Often the B.O.D. to be used must be selected from two B.O.D. values that appear equally satisfactory but are considerably divergent.

Low Solubility of Oxygen in Water:—The 9.17 p.p.m. dissolved oxygen that can be impressed into water, at 20° C. and 760 mm. atmospheric pressure, places confining limits on the variation of the B.O.D. that can be determined with any one dilution by the standard technique. Numerous methods have been suggested to either raise this limitation or to eliminate it all together. Gas analysis methods (9) have been suggested that supply oxygen to the sample in a closed system, the analysis of the remaining gas being used to determine the oxygen used by the sample. The same objective has been obtained more recently by manometric methods(10). A third method has been reported in which gaseous oxygen has been used in place of the air in the sample bottle (1). (The reaeration technique achieves this aim by introducing a new supply of dissolved oxygen into the sample as necessary to prevent total depletion.)

In addition to raising the solubility limitation, the reaeration technique eliminates all of the other difficulties listed above. Since the samples are not diluted, it is not necessary to prepare dilution water. A seed is not needed, blanks do not have to be determined, and a value is obtained that should be more closely representative of conditions in the stream.

Historical Background

The reaeration technique is not of recent origin. Theriault, McNamee and Butterfield (11) used this method to avoid total depletion of dissolved oxygen in their basic experiments on the selection of a satisfactory dilution water. The following quotation is taken from the discussion of an experiment in which 2 and 4 per cent sewage concentrations were used:

> In order to continue the experiment with 4 per cent mixtures, the contents of the 300 ml. bottles used for incubation purposes were poured into a large container and renerated by agitation in the presence of air. The

300 ml. bottles were then refilled by siphoning and a new figure was obtained for the dissolved oxygen content.
It is noteworthy, that this treatment of the 4 per cent mixtures was without effect on the subsequent agreement on the seventh and tenth days with the 2 per cent mixtures which were left undisturbed.

It should be noted in the above that all the diluted samples were incubated in sealed bottles. Kittrell and Kochtitzky (12) added the incubation of additional samples in a large open bottle to this technique and applied this modification to undiluted river samples. Orford, Rand and Gellman (13) used a reaeration technique to compare with the jug technique, in which the sample was also reaerated. While others have probably used a pooling technique, it is mentioned in the literature only by Heukelekian (7) and Snow (3).

The reaeration technique as outlined in this paper has been used routinely for several years by this laboratory, and its advantages in stream pollution studies seem so pronounced that it is felt a description of the techniques developed would be worth while.

Reaeration Procedure

Briefly, the reaeration technique consists of incubating several sealed bottles of a sample and a larger unsealed bottle of the same sample. The dissolved oxygen in the sealed bottles is measured by the Winkler procedure initially and at various intervals. When total depletion of the oxygen supply in the sealed bottles is approached another set of sealed bottles is prepared from the unsealed bottle and the process is continued through any time interval desired. The reaeration technique is outlined in the following steps:

1. The volume of sample needed for the determination of B.O.D. by the reaeration technique increases with the B.O.D. and the period of incubation desired. As shown below a 4-l. sample is sufficient for all 5-day B.O.D. determinations, but as many as 12 l. will be required for a 30-day B.O.D. of about 25 p.p.m. These volumes allow for daily determinations for the entire period.

Sample Volumes

B.O.D. p.p.m.	Incubation Period (Days)					
	5	10	15	20	25	30
	Liters					
5	2	4	5	7	8	10
10	3	5	6	8	9	10
15	3	5	6	8	9	11
20	4	5	7	8	10	11
25	4	5	7	8	10	12

2. The sample is adjusted to a temperature slightly in excess of 20° C. The exact temperature level is not critical, except as it affects Step 3 below. Experience indicates 23°–25° C. as the most desirable range.

3. The partly filled sample bottle is next connected to a vacuum line to remove any supersaturated oxygen that it might contain. This step is especially important during the winter or when an unusually high level of algal activity is expected. Under these circumstances considerably more D.O. than the 20° C. saturation value might be encountered. This saturation value varies with altitude and should be known for each laboratory.

If supersaturated oxygen is not removed, the sealed samples will develop minute bubbles upon incubation. When the sealed bottle is opened for the addition of the Winkler reagents, this excess oxygen escapes to the atmosphere. This results in a final D.O. that is lower than it should be, and consequently a higher B.O.D. result is obtained.

4. According to Buswell, Van Meter and Gerke (14) a variation in D.O. can be expected when a sample is

siphoned from one bottle to another in the presence of air. The technique developed to overcome this difficulty is that of maintaining the sample at the saturation level while the siphoning is being completed. The 23°–25° C. temperature adjustment in Step 1 decides the exact level of this saturation value, but in any event the resulting D.O. should not be much more than 8.5 p.p.m. (at sea level). Moggio and Burland (15) state that 15 min. bubbling with a diffusion stone is sufficient to assure a very stable D.O. level. Aeration for this time interval is suggested.

5. After the sample has been adjusted as indicated above, a slow rate of stirring is started to insure equal distribution of the suspended solids in the sample. A siphon is used to fill the necessary number of B.O.D. bottles to overflowing. After siphoning, the B.O.D. bottles should be left open for about one minute to allow the escape of any entrained air bubbles. The bottles are then sealed and the D.O. in one bottle determined by the Winkler procedure. The large bottle containing the remainder of the sample and the sealed bottles filled in this step, are placed in a 20° C. incubator.

6. After a period of time has elapsed, that is estimated to be considerably less than the time necessary for the B.O.D. of the sample to use all the available oxygen, a sealed bottle is removed from the incubator and the D.O. content determined. If the D.O. of the sample is approaching total depletion, reaeration of the sample will be necessary. If the D.O. remains high, another time interval can be allowed to elapse.

7. When the D.O. of the sample in the sealed bottles approaches 1 p.p.m., or will approach this level at an inconvenient time, the sample is reaerated. The sample bottle and the remaining sealed bottles are removed from the incubator and a final D.O. determination is completed on one of the sealed bottles. All excess sealed bottles are emptied into the sample bottle. This recombined sample is handled in much the same manner as a new sample would be, starting with Step 4 in the procedure and continuing through Step 6. This process returns the D.O. level to the saturation value, and maintains the sample in an aerobic condition for another interval of time. Inhibition of nitrite formation has been reported (16) at D.O. levels less than 2 p.p.m. It is, therefore, suggested that this value be used as the lower D.O. level during the active stage of nitrification.

These steps are repeated as many times as necessary to maintain aerobic conditions in the sample until the 5-day period or any other desired increment of time has elapsed.

Reaeration Device

A device has been designed to greatly facilitate the setting up and reaeration of samples by the above procedure. As shown in Figure 2 this device is composed of a magnetic stirring apparatus, a thermostatically controlled heater and various valves and tubes to control the flow of air and sample. The "Reaerator" is designed to fit 2½-, 3½-, and 5-gal. bottles requiring a No. 12 stopper. The sample is originally collected in one of the bottles. The sample bottle is then placed on the stand and the switches to the heater and stirring apparatus are turned on. A small pump provides aeration through a diffusion stone. Fifteen minutes are required for the sample to reach D.O. saturation level, and in the meantime the sample is automatically warmed to the correct temperature. Supersaturated oxygen is also eliminated in the same process. The magnetic stirrer insures a homogeneous distribution of suspended solids and also prevents excessive local heating of the sample near the points of contact be-

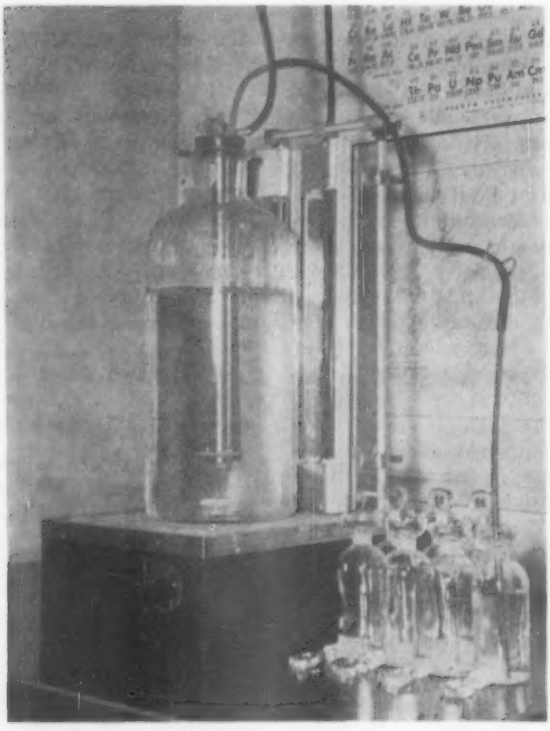

FIGURE 2.—Device for reaerating stream samples under controlled temperature conditions.

tween the bottle and the heater. When the sample has been warmed to the correct temperature and properly aerated, the vent stopcock is closed. This starts the siphon. The aeration pump is then turned off and as many B.O.D. bottles as necessary are filled.

It is not implied that a device such as this is necessary to the aeration technique, but the automatic features incorporated allow for the routine completion of the above procedure on many samples with a minimum of effort.

Applicability

This technique is basically designed to determine the B.O.D. of samples derived from streams and reservoirs. Some stream samples from areas of gross pollution will exceed the B.O.D. of 25 p.p.m. which is the upper practical limit of this technique. However, the percentage of such samples is considered to be only a small portion of all stream samples. Determination of the standard 5-day B.O.D. can be completed, in many cases, more conveniently than can the dilution technique, and long-term B.O.D. curves are easily obtainable by simply extending the interval of incubation and increasing the number of dissolved oxygen determinations.

Validification of Procedure

An attempt has been made to test the validity of the procedure given above. Experiments are shown that delineate precision, and an attempt was made to discover any possible errors related directly to the reaera-

tion technique. This latter objective was reached by comparing reaerated and unreaerated samples under carefully controlled conditions.

Precision

The precision to be expected when the reaeration technique is used is illustrated by Table I, with the individual daily values shown graphically in Figure 3. These five curves resulted from analyses of samples from the South Fork Holston River, Mile 0.5, with reaeration at 1.21, 4.25, 9.25 and 20.29 days.

Except for results of determinations at 0.17 and 0.25 days, for which the standard deviations are low, the standard deviations computed for all time periods are within the range of 0.26 to 0.59 p.p.m. Most of the variations apparently are related to items not directly associated with the size of the corresponding B.O.D. value. Variations in the rate of reaction due to the presence of an incipient growth phase, sampling errors incident to the original apportionment, and titration errors fall in this classification. The coefficient of variation tends to be fairly constant throughout the period of incubation, in the 2 to 3 per cent range, except for the first few values which correspond to low B.O.D. values. With the standard deviation being fairly constant, since it is due primarily to experimental errors, the coefficient of variation by its very nature tends to be larger for small values of B.O.D. In the determination at 0.17 and 0.25 days titration errors doubtlessly are important since a difference in the titration of one drop would cause considerable divergence in this low range.

If these results are representative of typical river samples, it could be concluded that in the range of B.O.D. covered by the reaeration technique, any one determination can be reproduced within approximately 1.5 p.p.m. This confidence limit will vary to some extent with the nature of the sample. Samples containing soluble matter almost entirely can be reproduced more exactly than samples containing particulate matter.

TABLE I—Precision of Reaeration Technique[1]

Time	Average B.O.D.	Standard Deviation	Coef. of Variation	95 Per Cent Confidence Limit
Days	p.p.m.[2]	p.p.m.	Per Cent	p.p.m.
0.17	0.48	0.03	6.2	±0.08
0.25	0.63	0.04	6.3	±0.13
1.21	4.28	0.38	8.9	±1.07
2.29	6.54	0.32	4.9	±0.89
3.21	7.98	0.38	4.8	±1.06
4.25	9.31	0.30	3.2	±0.83
5.17	10.40	0.28	2.7	±0.78
6.17	11.56	0.26	2.2	±0.72
7.17	12.39	0.31	2.5	±0.86
8.21	13.11	0.28	2.1	±0.78
9.25	13.74	0.36	2.6	±1.00
11.50	14.70	0.38	2.6	±1.06
12.17	15.00	0.33	2.2	±0.92
13.21	15.31	0.39	2.6	±1.08
15.21	15.87	0.36	2.3	±1.00
16.17	16.06	0.47	2.9	±1.31
17.33	16.33	0.43	2.6	±1.20
19.29	16.62	0.46	2.8	±1.28
20.29	16.77	0.52	3.1	±1.45
21.04	16.95	0.51	3.0	±1.42
22.38	17.11	0.53	3.1	±1.47
23.25	17.17	0.50	2.9	±1.39
24.25	17.40	0.38	2.2	±1.06
26.25	17.53	0.49	2.8	±1.36
27.25	17.66	0.53	3.0	±1.47
28.25	17.85	0.59	3.3	±1.64
29.04	17.91	0.56	3.1	±1.56
30.21	17.98	0.52	2.9	±1.45

[1] All replicates reaerated at 1.21, 4.25, 9.25 and 20.29 days.

[2] Arithmetic mean of five replicate samples.

Effect of Reaeration on B.O.D.

A large sample was collected from the Tennessee River, Mile 464.1, in which a low B.O.D. was expected. Settled sewage was added to raise the B.O.D. to the desired level. For the purposes of this experiment it was desired to have a sample that would

require neither dilution nor reaeration during the test period, but would show a significant increase in the B.O.D. for each time interval used.

This fortified sample was divided into two portions. The first portion was siphoned into a number of bottles to allow the initial and final D.O. determinations to be used as a control against which to compare the second portion of the sample. The second portion was treated in accordance with the reaeration technique with four reaerations being completed in 6 days of incubation. These four reaerations are the number usually required in a 30-day B.O.D. determination of about 20 p.p.m. The D.O. in the reaerated portion of the sample and the control was determined in each of five replicate samples.

As was noted under the procedure above, it was essential to maintain the control above the 2 p.p.m. level to prevent inhibition of nitrite formation. The reaerated sample varied in the range of 5 to 8.5 p.p.m. dissolved oxygen while the control continued progressively downward to 2.3 p.p.m. As shown in Table II, little difference in results from the two techniques can be noted. In only one instance was a statistically significant difference found, and in this case the difference amounted to only 0.13 p.p.m. A difference of 0.09 p.p.m. would have been statistically insignificant at the 95 per cent confidence level.

The data derived from this experiment indicate that the reaeration technique does not materially affect the B.O.D. reaction.

Disadvantages

In considering acquiring the advantages inherent in the reaeration technique certain disadvantages must also be accepted. The B.O.D. of all samples from streams and reservoirs cannot be determined by this technique. The method is considered impractical for samples exceeding a 5-day B.O.D. of about 25 p.p.m. The frequent reaerations necessary to maintain an oxygen excess in the sample

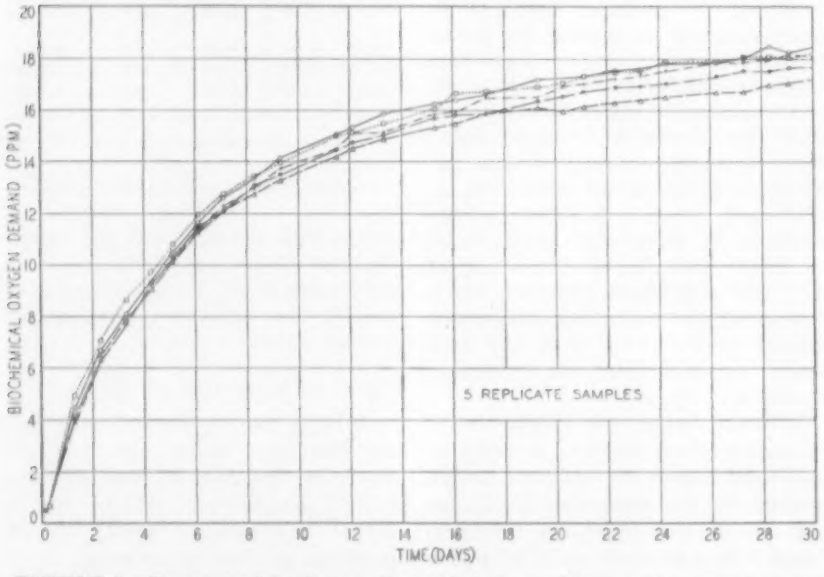

FIGURE 3.—Demonstration of reaeration technique precision on long-term B.O.D.

TABLE II.—Effect of Reaeration on B.O.D.

Time	Control (Unreaerated)		Sample (Reaerated)			Difference
	B.O.D.[1]	Standard Deviation	Cumulative No. of Reaerations	B.O.D.[1]	Standard Deviation	B.O.D.
Days	p.p.m.	p.p.m.		p.p.m.	p.p.m.	p.p.m.
0.81	1.59	0.03	0	1.59	0.07	0.00
2.00	2.45	0.07	1	2.58	0.07	0.13[2]
3.73	3.76	0.04	2	3.73	0.06	0.03
4.96	4.26	0.06	3	4.22	0.09	0.04
5.71	4.52	0.08	4	4.44	0.08	0.08

[1] Average of five determinations.
[2] Indicates a statistically significant difference at the 95 per cent confidence level.

during the initial upsurge of carbonaceous demand requires excessive effort on the part of the analyst for these high B.O.D. samples. Since occasional samples from grossly polluted streams will be encountered, this necessitates the use of other methods. The use of a single dilution technique, as suggested by Orford, Rand and Gellman (13), in conjunction with the procedure described above will readily extend the range sufficiently to cover these occasional high B.O.D. samples.

Other disadvantages of a less basic nature are the larger sample volume required, and the somewhat larger incubator space requirements. A 5-day B.O.D. requires about 55 sq. in. of shelf space. This should be compared with about 25 sq. in. for a three level dilution sample and about 75 sq. in. for the jug technique. Finally, the reaeration technique requires more attention after the initial set-up is completed. This disadvantage is partly compensated by frequently requiring less time to set up a sample.

Summary

A procedure has been outlined for the determination of B.O.D. by a reaeration technique. Precision of the proposed technique has been demonstrated to be within reasonable limits. The extent of errors related directly to the reaeration technique are believed to be of an insignificant nature in the practical application of the determination.

This technique has broad usefulness to pollution control agencies and other groups interested in studying the water quality of streams and reservoirs. It is felt that the reaeration technique outlined here represents considerable progress toward a closer reproduction of natural stream conditions in the B.O.D. determination.

Acknowledgment

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INTERCEPTOR AND SEWAGE TREATMENT PROGRAM AT KNOXVILLE, TENNESSEE *

By Leonard C. Bailey

City Engineer, Knoxville, Tenn.

Abatement of stream pollution in Tennessee is rapidly gaining momentum due to the program adopted around 1945 by the State Stream Pollution Board. It is a source of great satisfaction to know that Knoxville was probably the first of the four large cities of the state to complete its sewage interceptor and treatment plants and get them into full operation.

In 1954 conditions in Knoxville were similar to those of other cities of similar size. That is, the city's raw sewage had been placed in the Tennessee River, which is now the Fort Loudoun Lake, during the entire history of the city. In fact, the city was placing 24.2 m.g.d. of sewage into the Fort Loudoun Lake through 32 sewer outfalls ranging in size from 8 in. to 60 in. This included sewage from approximately 29,000 sewer connections throughout the city and about 500 residential connections outside the city. These outfalls also handled the sewage of the Fountain City Sanitary District, which is probably the largest unincorporated area in the United States and lies just north of Knoxville. This connection added an additional 0.25 m.g.d. of sewage and it is expected to increase perhaps to 0.5 to 1.0 m.g.d. in the near future.

Financing

Knoxville's stream pollution abatement program was begun in December 1945, when an original report was presented to the Mayor and the City Council by the consulting engineers. At that time, the engineers were authorized to proceed with plans and specifications and such plans were completed during 1948. In the fall of 1951 a referendum was held and the citizens authorized the issuance of $6,000,000 in sewer revenue bonds to construct this project. On July 1, 1953, bids were received on construction and work was ordered to begin on all contracts not later than September 1, 1953. At the same time the sewer revenue bonds were sold July 1, 1953, in the amount of $5,000,000 as Series A. The balance of $1,000,000 in bonds was sold in December 1954 in order to complete the work.

A contract was signed with the Knoxville Utilities Board to start collection of the sewer service charges as of July 1, 1953. It was decided at the outset that all construction, operation and maintenance of plants and interceptors was to be handled by the City Engineer's Office. This was agreeable with the Knoxville Utilities Board, although the first choice of the city was to turn the construction, operation and maintenance over to that board.

The Knoxville sewage disposal project consists of 10 mi. of intercepting sewer 10 in. to 84 in. in diameter, with two river crossings, two sewage pumping stations, and two treatment plants.

A small plant, known as the Loves Creek treatment plant, is on the Holston River where Loves Creek enters it about 7 mi. above the municipal water plant in Knoxville and

* Presented at 1954 Annual Meeting, Kentucky-Tennessee Industrial Waste and Sewage Works Assn.; Nashville, Tenn.; Sept. 21, 1954.

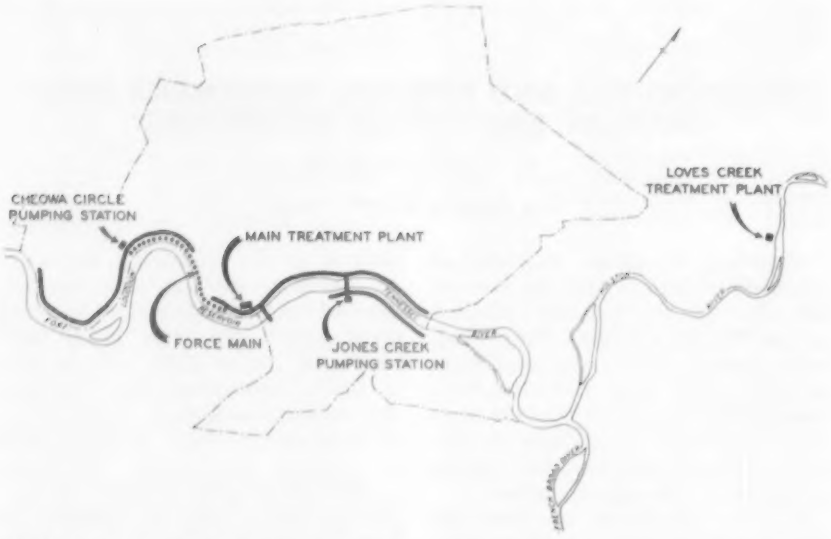


FIGURE 1.—Location of major installations in Knoxville, Tenn., sewerage and sewage treatment program.

serves an area of Knoxville known as Burlington, where it is more economical to pump the sewage to the Holston River than pump it to the large interceptors on the north bank of the Tennessee River and then into the main treatment plant.

The large plant, known as the Third Creek treatment plant, is on the north bank of the Fort Loudoun Lake at the intersection of Third Creek where the sewage from both sides of the lake, exclusive of the Burlington area, is pumped or carried by gravity to this one station.

One of the sewage pumping stations known as the Jones Street pumping station, is on the south side of the river. It pumps the sewage intercepted for the largest part of the south side to the north side interceptor, thence into the main treatment plant. Another interceptor chamber on the west and south side of the city sends the sewage of that area by siphon across the lake into the main treatment plant interceptor. The second pumping station is known as the Cheowa Circle pumping station and is located in the Sequoyah Hills area of Knoxville, which is downstream from the main treatment plant. Therefore it is necessary to pump the sewage back up the river or lake to the main treatment plant (see Figure 1).

The total estimated cost of this construction project was as follows:

Interceptors, force mains, and river crossings	$2,850,000
Cheowa Circle and Jones St. pumping stations	234,089
Loves Creek treatment plant	285,360
Third Creek (main) treatment plant	1,960,864
Total construction cost	$5,330,313

In addition there were further expenses to this project, as follows:

Repayment to the FHA for plans and specifications	$110,000
Engineering, supervision, etc.	155,000
Financial, bonds, etc.	55,000
Rights-of-way, sites, etc.	85,000
Contingencies	264,687
Total other expenses	$669,687

When these other expenses were added to the construction costs, the total issue in bonds of $6,000,000 is accounted for. The construction costs represent original bids as submitted by the contractors. It was anticipated that most of the contingency fund would be taken up by construction needs.

Design Basis

The design of the several parts was based on the following factors:

Population Served

Plant	Design	Future
Third Creek (main)	261,000	400,000
Loves Creek	7,600	13,250
Both	268,600	413,250

In addition, 14 industries in Knoxville alone have an equivalent population of 158,000 people. Therefore, the total equivalent design load for industry was taken to be 300,000 persons.

Plant and Interceptor Layout

Loves Creek treatment plant—Comprised of two-story sedimentation tanks and sludge drying beds with pre-chlorination.

Design basis	1.4 m.g.d. (av. 1965)
Ultimate	2.5 m.g.d. (av. 1995)
Present	0.5 m.g.d.

Third Creek treatment plant—Comprised of separate sedimentation and digestion tanks, equipment for dewatering sludge with vacuum filters, and facilities for pre- and post-chlorination and future secondary chemical treatment if necessary.

Design basis	35.7 m.g.d. (av. 1965)
Ultimate	50.7 m.g.d. (av. 1995)
Present	24.2 m.g.d.

At the Loves Creek treatment plant, there is a small pumping station which has a wet well and a small detritus tank. The latter serves as a grit settling basin. Sewage containing the grit is pumped from the hopper at a constant rate through a small grit chamber, and thence into an Imhoff tank. The balance of the sewage is pumped directly into the Imhoff tank.

The sludge is dried on sand beds. Pre-chlorination facilities are provided so that although the treated effluent still contains about two-thirds of its biochemical oxygen demand, it is practically free of pathogenic bacteria. The intercepting sewers and force mains have sufficient capacity to serve until 1995.

The Third Creek sewage treatment plant provides primary treatment and chlorination. The structures, however, are arranged to provide chemical precipitation later, if necessary.

The principal structures consist of a two-unit grit chamber, four settling tanks with a raw sludge pumping station, a Parshall flume for quantity measurement, three sludge digestion tanks with a sludge control building, elutriation tanks for sludge preparation prior to vacuum filtration, a chlorine building and chlorination equipment, and a main building. The main building houses the bar screens and grinders, the wet well, pumping equipment, sludge filtering equipment, offices, a laboratory, locker rooms, and assembly room for various uses.

Expected Removals

In order to consider what this investment is buying for the citizens of Knoxville, it is necessary to understand the sewage characteristics as found by the surveys (Table I).

It is estimated that the plants reduce the suspended solids by 45 to 50 per cent and the 5-day B.O.D. by 30 to 35 per cent.

Paid for by Service Charges

The total estimated annual cost to the citizens of Knoxville during the years 1954 to 1987 inclusive has been estimated to begin with $468,600 in 1954 and gradually increase to $612,175 per year. These figures include operating costs, maintenance, and prin-

TABLE I.—Suspended Solids and B.O.D. Loads Expected at Knoxville Sewage Treatment Plants

Plant	Susp. Sol. (lb./day)			B.O.D. (lb./day)		
	1945	1965	1995	1945	1965	1995
Main	42,000	55,000	73,500	49,500	62,500	80,000
Loves Creek	640	1,430	2,250	600	1,350	2,100

cipal and interest payments on the bonds.

The service charges now in effect charge the users of city sanitary sewers an amount which equals approximately 60 per cent of their charge for water service. The minimum charge is $0.51 and includes 500 cu. ft. or less for those users inside the city limits. For those outside the city limits the minimum charge for the same service is $0.75.

The charges established by the City Council were expected to bring in $644,500 for the first full year of collection and until 1987 will gradually increase until the total amount is $1,064,400 per year. As previously stated, these charges have been in effect since July 1, 1953. During this time no particular trouble has been experienced in collecting the rates and it is believed that the people of the city are wholeheartedly in support of the project.

The project is complete insofar as the intercepting sewers and the plants are concerned. The Loves Creek treatment plant, for example, started operation late in 1954, with the Main treatment plant being put into operation in the Spring of 1955.

JULIUS W. BUGBEE, HONORARY MEMBER, DIES

One of the first Honorary Members of the Federation (1942), Julius W. Bugbee, 84, well-known New England sanitary engineer, died at Providence, R. I., on July 20, 1955. He was an 1890 graduate of Worcester Polytechnic Institute. Most of his professional life was spent on water works and sewage treatment projects at Providence, R. I. where he was superintendent of the sewage treatment plant at the time of his retirement in 1943.

Mr. Bugbee was active in Federation activities, having served as a director from the New England Association in 1932. He was a former president of the New England Sewage Works Association and a member of the Quarter Century Operators' Club.

MECHANICS OF OXYGEN ABSORPTION IN SPIRAL FLOW AERATION TANKS

II. Experimental Work

By Henry R. King

Senior Civil Engineer, The Sanitary District of Chicago, Ill.

Formulas have been derived * for computing the rates of oxygen absorption occurring in spiral flow aeration tanks. This was done by applying to the velocities of circulation as measured in a large aeration tank, experimental data available pertaining to the rates at which oxygen enters solution from rising air bubbles and atmospheric reaeration.

However, to be certain that formulas so derived are reasonably accurate, experimental proof is required. For that reason a number of tests have been made, as described hereafter.

Oxygen Absorption Testing Equipment

Measurements of the rates at which oxygen is absorbed by water were made in three small tanks of 10-, 20- and 36-in. depth on the diffusers. These are shown in Figure 4. They closely approximated 1/18-, 1/9-, and 1/5-scale models, respectively, of the 15-ft. depth (to diffusers) tank upon which the basic computations for the formulas were made.

The 10-in. tank had one row of diffusers, equivalent to plate area of 5 per cent; the 20-in. tank had one to three rows, equivalent to plate area ratios of 2.5, 5.0, and 7.5 per cent, respectively; the 36-in. tank had a removable holder for one 12-in. by 12-in. plate diffuser, equivalent to a plate area ratio of 10 per cent. The diffusers in the 12- and 20-in. tanks were porous silica plates of 3/8-in. thickness. Alumina and silica porous plates of 1- and 1½-in. thickness, respectively, were tested in the 36-in. tank.

The air was measured by means of orifice meters connected to water manometers. The meters for the two smaller tanks were calibrated by volumetric measurements. All rates of air flow were registered as free air at 29.3 in. Hg (14.4 lb. per sq. in. abs.) and 60° F.

Test Procedures

The oxygen absorption rates were determined by two methods: (a) aeration of pre-deaerated water and (b) aeration of sodium sulfite solution. The results obtained with deaerated water are the true rates of oxygen absorption. Aeration of sodium sulfite solution, however, proved to be the more practical method. Therefore, deaerated water was used to establish the correction factor to be applied to the measurements made by means of the sulfite solution, the method used for most of the tests reported on here.

In the aerating of deaerated water by means of diffused air, the rate of absorption of oxygen, where all other conditions remain unchanged, varies directly as the oxygen deficiency for the absolute pressure of some depth less than half depth. The smaller the air bubbles, the greater this depth. The relation of oxygen deficiency and rate of oxygen absorption (6) can

* Part I of this series was published in the August 1955 issue of This Journal.

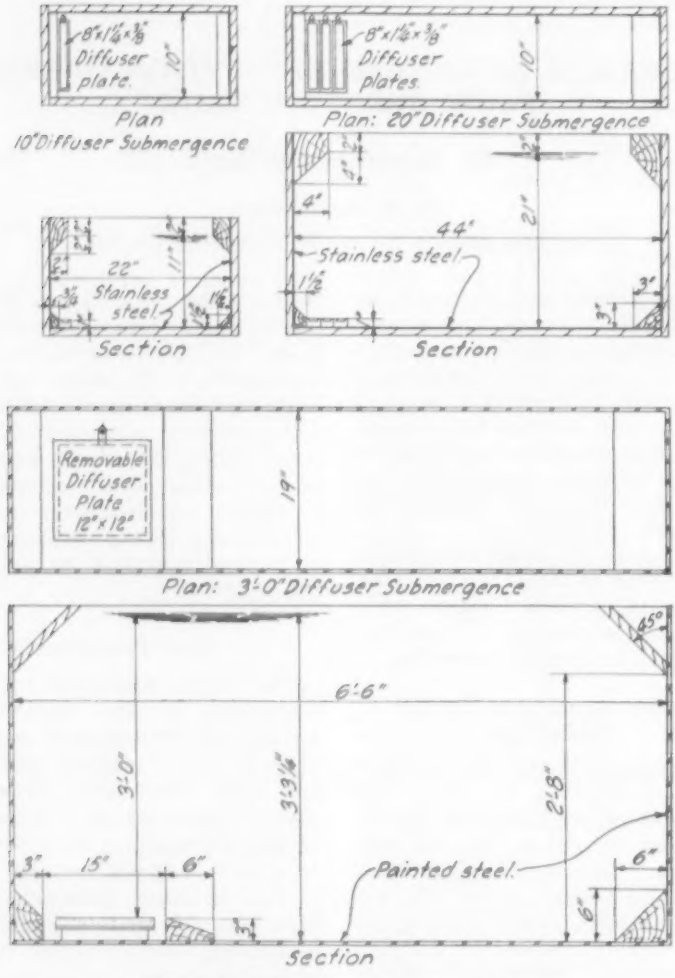


FIGURE 4.—Experimental aeration tanks.

be expressed by the differential form,

$$\frac{dUe}{Ue} = K\,dt \quad \ldots\ldots\ldots (9)$$

in which Ue is the oxygen deficiency at the partial depth. Integrating and converting to common logarithms, Eq. 9 becomes

$$\text{Log } Ue - \text{Log } Ue_t = \frac{K\,t}{2.3} \quad \ldots (10)$$

in which Ue is the initial oxygen deficiency, in p.p.m., at zero time; Ue_t is the deficiency after time, t; and K is the rate of oxygen absorption per unit of time, expressed in p.p.m. per p.p.m. of oxygen deficiency at the partial depth.

The proper partial depth to be used can be determined by aerating for a prolonged period at constant temperature and barometric pressure to insure D.O. saturation. The D.O. then obtaining will exceed that of saturation

at atmospheric pressure and will correspond to the pressure of the depth at which the rate of absorption varies directly as the D.O. deficiency, that is Ue.

Due to experimental error the determination of the partial depth may not be exact. However, if the rate of absorption is expressed as total rate (that is, the product of K multiplied by deficiency) the error is reduced. It should be noted that the depth to be used changes with bubble size and diffuser plate area.

In some instances it may be desirable to know the partial depth to be used in Eq. 10 without being able to determine it experimentally. It can be estimated for 5 or 10 per cent diffuser plate area if the approximate air bubble size is known. First, the percentage of the absorption occurring at the surface, including bubble bursting effect, should be computed. The absorption rate at the surface varies as the oxygen deficiency at atmospheric pressure, whereas that for the rising bubbles varies as the deficiency for pressure of about half depth. From this basis it is possible to compute the depth for use in the formula.

Most of the tests were run in tap water. A few, however, were made in distilled water. The D.O. was removed from the water prior to each test by (a) heating and cooling, (b) adding dry ice to it, or (c) diffusing nitrogen into it. The latter two methods removed the major part of the D.O. present by the desorptive effect of the rising gas bubbles, devoid of oxygen.

Air was diffused into the deaerated water; 250-cc. samples were removed at intervals and D.O. determinations were made by the modified Winkler method. By plotting the results on semi-log paper (Figure 5) and using Eq. 10, the values of K were obtained. These have been expressed in p.p.m. oxygen absorption per hour per p.p.m. oxygen deficiency at partial depth.

The aeration of sodium sulfite solution differs from that of deaerated water in that a constant, rather than a varying oxygen deficiency, obtains. For sulfite concentrations above 300 p.p.m., such as used in the tests, the D.O. remains at zero, as the oxygen going into solution immediately unites with the sulfite to form sulfate, the reaction being as follows:

$$Na_2SO_3 + O \text{ (from the water)} = Na_2SO_4$$

By measuring the decrease in sulfite concentration in relation to time, the rate of oxygen absorption can be readily determined. This can be done by collecting at intervals a sample of fixed amount from solution and adding to this a predetermined amount of acidified iodine solution. The iodine unites with the sulfite, the reaction being:

$$Na_2SO_3 + I_2 + H_2O = Na_2SO_4 + 2HI$$

By adding each sample to such a fixed amount of iodine solution that there is always iodine in excess of the amount required to neutralize the sulfite solution, the change in sulfite concentration can be determined by measuring the change in the excess iodine for each interval. This is done by titrating the excess of iodine with N/40 thiosulfate. For a 50-cc. sample of the sulfite solution, a titration of 1.0 cc. of the sodium thiosulfate is equivalent to 4 p.p.m. of oxygen absorption.

Tests on sulfite solution were made in the three experimental tanks. The procedure was about as follows. Sodium sulfite to the amount of 1,200 p.p.m. was added to the water in a tank and about 100 p.p.m. of 66° Baume sulfuric acid. The acid had no apparent effect on results, but was added because it was felt more consistent results might occur when the concentration of the unconverted sulfite was low.

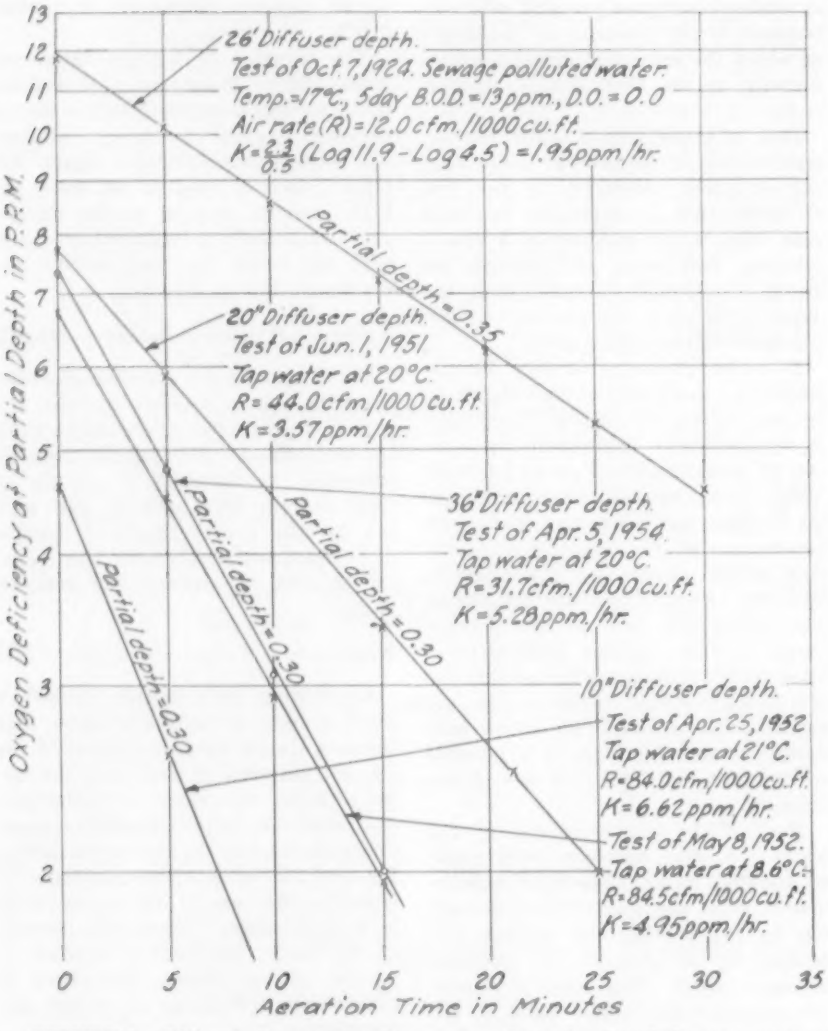


FIGURE 5.—Diffused air tests, showing oxygen absorption in relation to oxygen deficiency at partial depth.

The air diffusion rate was set and samples were taken with a 50-cc. pipette at 10-or 15-min. intervals for periods of from 30 to 60 min. The samples were added to a fixed amount of iodine and titrated with thiosulfate solution to determine the oxygen absorption rate. Measurements were made until the sulfite concentration was reduced to about 300 p.p.m., when it was discarded and another run was started with a new solution.

The amount of sulfite added to the water had an effect on the results obtained. The rate of oxygen absorption increased as more sulfite was added; about 1 per cent higher results occurred for each 100 p.p.m. added.

TABLE IV.—Results of Tests Under Various Solution Temperatures

Test No.	Solution Temp. (°C.)	0.3 Depth (6 in.)		Oxygen Absorption (p.p.m./hr.)		
		Abs. Press. (in. Hg)	Oxygen Def. (p.p.m.)[1]	Test Results		Per p.p.m. (K) Oxygen Def.[2]
				Total	Per p.p.m. (K) Oxygen Def.	
(a) April 3, 1952; k = 4.25						
1	11.1	29.93	11.05	60.5	5.47	5.48
2	18.0	29.93	9.54	61.9	6.50	6.45
3	26.0	29.94	8.22	63.5	7.73	7.73
(b) April 8, 1952; k = 4.39						
1	10.15	30.23	11.40	63.4	5.56	5.56
2	18.0	30.23	9.64	64.7	6.70	6.67
3	26.3	30.23	8.25	67.1	8.10	8.07
4	10.4	30.23	11.37	63.0	5.54	5.50

[1] D.O. = 0 p.p.m.
[2] $K = k\,1.024^T$.

The tests were standardized on an addition of 1,200 p.p.m. and the absorption rates thus obtained were compared with results on deaerated water.

Several factors affecting the results obtained with both sulfite solution and deaerated water had to be considered. The thiosulfate solution was used in both measurements. Therefore, its correct standardization was important. To eliminate errors, the D.O. of saturated tap water into which air had been diffused for a day at a depth of about 4 in. was determined and the value in relation to saturation (Standard Methods) for the particular barometric pressure and water temperature furnished a correction factor which was applied to all measurements made with the particular thiosulfate solution used in the titrations.

Another important factor to be considered, not realized in the beginning of the tests, was the effect of moisture in the pores of the diffuser plates. By soaking a diffuser plate for several hours or more, the rate of oxygen absorption could be increased over that for the plate if started up dry.

The improvement varied from 0 to 25 per cent or more with new plates, increasing with grain size, and as much as 30 per cent or more for plates that had been in service in the activated sludge process. Soaked plates gave consistent results on repeat runs. Therefore, in the latter part of the tests each diffuser was submerged for several hours or days before an oxygen absorption measurement was made.

Effect of Temperature

The effect of temperature on oxygen absorption was measured by aerating sulfite solution in the 20-in. depth (to diffusers) tank. The diffuser area was 5 per cent and the diffusion rate 62.5 c.f.m. of air at 29.3 in. Hg (14.4 lb. per sq. in. abs.) and 60° F. per 1,000 cu. ft. of solution. In running the experiment, all conditions were maintained the same except the water temperature. The test at each temperature was made starting with a fresh 1,200-p.p.m. solution of sulfite. The results are given in Table IV.

It is to be noted that, for the range of temperature in the tests, the rate

TABLE V.—Results of Two Tests at Different Water Temperatures

Date	Water Temp. (°C.)	Air Rate (c.f.m./1,000 cu. ft.)	Abs. Press. 0.3 Depth (in. Hg)	Oxygen Absorption, K, at 0.3 Depth (p.p.m./hr.)[1]	
				Test	$k(1.024)^T$
					$k = 4.06$
4/25/52	21.1	84.0	29.87	6.62	6.62
5/ 8/52	8.6	84.5	29.77	4.95	4.95

[1] Per p.p.m. oxygen deficiency.

of oxygen absorption per p.p.m. D.O. deficiency varied as $k(1.024)^T$, in which k is a constant, 1.024 is the temperature coefficient, and T is the temperature in degrees Centigrade. The slightly higher value of the constant, k, in the tests of April 8 was probably due to some small change in the division of the air between the two diffusers. For the tests in any one day, however, the distribution of the air remained unchanged.

Tests to check the effect of temperature on the rate of oxygen absorption also were made, using deaerated water instead of sulfite solution. The 10-in. depth (to diffusers) tank was used for this purpose. The diffuser was soaked prior to each test to be sure the character of the air diffusion remained unchanged. The results of two tests (Figure 5), practically identical except for temperature, were as given in Table V.

The values of K were computed by Eq. 10 from test results shown in Figure 5. The results check the sulfite solution tests in indicating that the oxygen absorption rate per p.p.m. oxygen deficiency varies as 1.024^T.

A study of the test data on temperature effect indicates that the rate of oxygen absorption at zero D.O. increases slightly with a rise in water temperature, varying from 0 at 5° to 0.4 per cent at 25°, per degree Centigrade increase in temperature.

Haslem, Hershey and Keen (13) measured the rates of absorption of sulfur dioxide by water. The gas was blown up through a tower of the wetted wall type. Analysis of the data indicates that for the higher gas velocities (0.5 to 1.5 ft. per sec.) and a temperature range of 10° to 30° C., the value of K varied about as 1.024^T. The solubility of SO_2 is about 3,000 times that of oxygen. Therefore, over a wide range of solubility the rates of absorption of gases by water must be similarly affected by temperature.

Correction Factor for Sulfite Tests

The correction factor to be applied to all the results obtained with sulfite solution in order to convert them to clean water was determined in the 10-

TABLE VI.—Results of Tests to Determine Correction Factor for Sulfite Tests

Test	Liquid Temp. (°C.)	0.3 Depth[1]		Oxygen Absorption, K, at 0.3 Depth (p.p.m./hr.)[2]	
		Abs. Press. (in. Hg)	D.O. Sat. (p.p.m.)	Test	8.6° C.
Water	8.6	29.81	11.65	4.95	4.95
Sulfite sol.	10.5	29.81	11.05	5.53	5.28

[1] 3 inches.
[2] Per p.p.m. oxygen deficiency.

in. depth tank. First it was filled with water which was deaerated by means of heating and cooling. The oxygen absorption rate (test of May 8, 1952; Figure 5) of the deaerated water was determined for an air rate of 84.5 c.f.m. per 1,000 cu. ft., and then, without changing the air, sulfite (1,200 p.p.m.) was added and an absorption determination made. This procedure insured identical air diffusion for both determinations. A small difference in temperature of the liquid occurred. This was adjusted for by means of the temperature coefficient. The results are given in Table VI.

This test indicates the oxygen absorption rate in clean water to be 4.95/5.28, or 93.5 per cent of that in a sulfite solution of an original addition of 1,200 p.p.m. Approximately this same relation was obtained by selecting deaerated water and sulfite solution tests for comparison in which it seemed the air diffusion must have been very similar and adjusting for temperature differences; but such procedure was not as precise as the foregoing test. All results reported hereafter are for clean tap water and those obtained with sulfite solution have already been corrected to water by multiplying by 0.935.

One test (July 12, 1952) with deaerated distilled water in the 10-in. tank indicated the same oxygen absorption rate as obtained for tap water.

Experiments Pertaining to Formulas

Experiments were undertaken to show that the formulas are correctly set up and reasonably accurate. It was possible in several instances to know the values of all the variables, (the bubble diameter, however, by indirect methods). In these cases the results by means of the formulas checked with tests. However, to prove that these were not just coincidences, tests were made to show that the formulas correctly reflect the effects of the various variables included therein. Before proceeding with the discussion, the general formulas (Eqs. 6 and 7) should be converted to the depths used in the experiments. In the converted forms they are as follows:

Diffusers		Oxygen Absorption	
Depth (in.)	Area (%)	Equation	Eq. No.
10	5	$A = \frac{0.0213 U^{1.02} R^{0.935} (1.024)^T}{d^{0.64}}$	11
20	5	$A = \frac{0.0349 U^{0.93} R^{0.935} (1.024)^T}{d^{0.64}}$	12
36	10	$A = \frac{0.0398 U^{0.90} R^{0.86} (1.024)^T}{d^{0.70}}$	13

in which

A = oxygen absorption, in p.p.m. per hour;

U = oxygen deficiency for water, in p.p.m., at atmospheric pressure;

R = air diffusion rate, in c.f.m. per 1,000 cu. ft. of water (free air at 60° F. and 29. 3 in. Hg abs.); and

D = weighted average diameter of air bubbles, in inches.

Effect of Diffuser Area

A test was made to determine the effect of the diffuser area. The oxygen absorption rate was measured for the 20-in. depth at a constant rate of air application of 62 c.f.m. per 1,000 cu. ft. of water with 1, 2 and then 3 diffusers, equivalent to plate areas of 2.5, 5.0 and 7.5 per cent. From a plotting of the results, it was concluded that a rate of absorption about 8 per cent higher would obtain for a diffuser plate area of 10 per cent than for an area of 5 per cent. As a result of this test and tests with known bubble sizes, the formula for 10 per cent diffuser area was revised, as previously pointed out, to give 5 per

cent higher absorption at 1-ft. depth than in the form originally derived. With this revision, the differences in absorption rates indicated by the formulas for 5 and 10 per cent diffuser plate areas are in closer accordance with test results.

Atmospheric Reaeration

The computations on which the formulas are based indicated atmospheric reaeration accounted for about 25 and 40 per cent of the total oxygen absorption rate for 0.1- and 0.2-in. bubbles, respectively, for 5 per cent diffuser plate area; and 20 and 30 per cent of the total absorption for 10 per cent diffuser plate area. These percentages are approximate, since they vary some with depth, oxygen deficiency and air application rates.

Tests were made to determine if the part of the oxygen absorption due to atmospheric reaeration corresponded to that computed in deriving the formulas. One method of doing this was to set up an overturning circulation in the 20-in. depth tank, measure the absorption rate, and compare this with the absorption rate occurring with air diffusion when producing the same surface velocity. A Pitot tube with the water column inclined at a very slight angle to the horizontal was used to gage the intensity of the surface velocities. The percentage of the oxygen absorption attributable to the surface by this test corresponded closely with that computed.

In another test, diffused nitrogen instead of air was used in an effort to measure the oxygen absorption attributable to atmospheric reaeration. To do this, a cylinder of nitrogen was connected into the air supply piping system of the experimental setup. Thus it was possible to meter and diffuse either air or nitrogen into sulfite solution or water in any one of the three tanks. However, when nitrogen was diffused into sulfite solution, bubbles of nitrogen floated across the surface for various distances before breaking.

The desorptive effect of these nitrogen bubbles and the reduced percentage of oxygen in the air just above the surface, due to the diluting effect of nitrogen, must have reduced the oxygen absorption rate at the surface below that which occurred for the same rate of air diffusion. The oxygen entering solution at the surface was less than that computed for air diffusion. But as the rate of nitrogen diffusion was decreased, the floating bubbles and diluting effect of the nitrogen above the surface diminished. As a result, the measured surface absorption with diffused nitrogen increased relative to the total absorption for air diffusion as the rate of application was reduced, and tended to approach the computed percentage at very low rates. This held true for both 20- and 36-in. diffuser plate submergence.

Theoretically, the same law applies to the release of gases (1) as to their absorption. Therefore, it was to be expected that rising bubbles of nitrogen would remove oxygen from water containing D.O. at a rate equal to that at which rising bubbles of air at the same rate and size increase it; that is, per p.p.m. difference in the oxygen concentration across the gas-water interface.

That this must be true was demonstrated by tests. Starting with oxygen-saturated water in a tank, nitrogen was diffused into the water at a constant rate and the D.O. determined at intervals. Logarithmic plotting of the D.O. in relation to time, until it had decreased 2 to 3 p.p.m. below saturation, gave the K_2 or oxygen removal rate, for the rising bubbles of nitrogen and that due to the escaping nitrogen over the surface. This was possible since, with the D.O. near saturation, the oxygen absorption from the atmosphere was negligible and could be disregarded with only a slight

error in the determination of the rate of removal of the dissolved oxygen by means of the diffused nitrogen.

The results of such a test are shown in Fig. 6 for the 36-in. depth tank. It is to be noted that for a diffusion rate of 31.8 c.f.m. per 1,000 cu. ft. of water, the oxygen desorption rate using nitrogen was about 89 per cent of the oxygen absorption rate that occurred with air. The desorption rate with nitrogen was that due to the rising bubbles plus that due to the concentration of nitrogen just above the water surfaces where the velocities were highest. For the particular diffuser used in the test, the absorption attributable to the air bubbles computed at about 81 per cent of the total. The difference between this and the desorptive effect of the diffused nitrogen (89 per cent) could reasonably be due to the desorption due to the nitrogen released at the surface of the water.

The foregoing desorption rate of diffused nitrogen expressed as a percentage of the absorption rate for air diffused at the same rate was checked by diffusing air and then nitrogen into sulfite solution in the 36-in. depth tank, using the same diffuser and diffusion rate as in the test previously described. The oxygen absorption rate with diffused nitrogen was about 10 per cent as much as that with diffused air.

From the tests made to determine the part of the oxygen absorption in the diffused air aeration due to atmospheric reaeration, it was concluded that it must be approximately as it was computed and used in the derivation of the formulas.

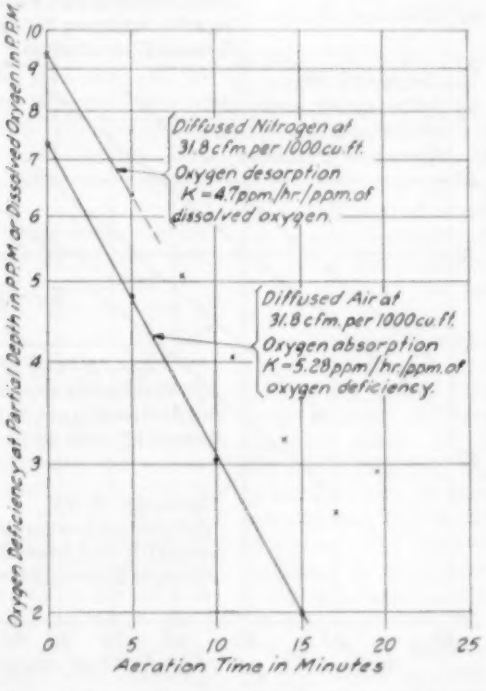


FIGURE 6.—Comparison of oxygen absorption by air and oxygen desorption by diffused nitrogen (water temperature, 20° C.; diffuser submergence, 3.0 ft.)

Effect of Rate of Air Application

The results of four tests, typical of those made in checking the effect of the rate of air diffusion, are shown in Figure 7. Each test was for some particular diffuser plate area and depth, for which the rate of oxygen absorption was measured at three different rates of air application. The bubble diameter at one of the three rates was computed for the absorption rate obtained, using the oxygen absorption formula applicable to the conditions of the test. Then, using this bubble diameter, a line was drawn in accordance with the formula, showing the relation of air application to oxygen absorption. The fact that for each test the line passes very closely to the experimental results is a good indication that the formulas show correctly the effect of the rate of air application for any particular bubble size.

Effect of Depth

A test was made as a direct check on the effect of tank depth. This was done for a 5 per cent diffuser area. The absorption rate was measured for the 20-in. depth. Then the two diffusers from this tank were moved one at a time to the 10-in. depth tank and the absorption rate was measured for each. This procedure was a means of being sure the same bubble size obtained for the two depths. The results are shown in Figure 7 as Tests No. 1 and No. 2 of April 8, 1952. A line has been drawn through the plotted results for the 20-in. depth (Test No. 1) in accordance with the formula, using a 0.102-in. bubble. Using this

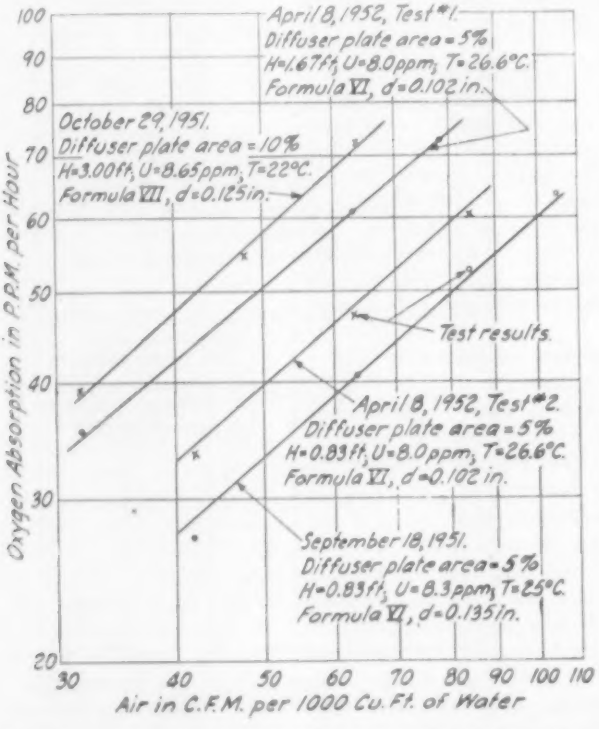


FIGURE 7.—Oxygen absorption by water in experimental tanks. Tests made with sulfite solution, results converted to clean water ($C = 1.0$).

same bubble size, the formula gives another line for the 10-in. depth passing very close to the experimental results obtained in Test No. 2. This is good evidence that the factors included in the formulas are correctly related to reflect the effect of depth.

Effect of Oxygen Deficiency

The general formulas, within the limits specified, indicate that the oxygen absorption varies as a function of the oxygen deficiency based on atmospheric pressure. That this is true can be demonstrated by the results of tests. The Sanitary District measured the rates of oxygen absorption by sewage polluted water with air diffusing at 26-ft. depth in the Lockport lock of the Sanitary District Main Channel in 1924 and 1925. The results of a typical test are shown in Figure 5, in which the oxygen deficiencies for the pressure at 0.35 depth are plotted in relation to time for a constant rate of air application. It is to be noted that the results of this test are in accordance with Eq. 10, which simply means that the rate of absorption varies directly as the oxygen deficiency at some particular partial depth.

Also shown in Figure 5 are similar tests for air diffused at 10-, 20- and 36-in. depths in tap water. The several sets of tests indicate that over a wide range of depth, the rate of oxygen absorption with air diffusion varies directly as the oxygen deficiency at some partial depth. Using this conclusion as a basis, it can be shown that the oxygen deficiency for atmospheric pressure, raised to the powers indicated by Eqs. 6 and 7, vary directly with the oxygen deficiency at partial depth within the range of oxygen deficiency (zero to 50 per cent at atmospheric pressure) for which these general formulas are applicable. Therefore, they must also correctly reflect the effect of varying oxygen deficiency.

Lockport Aeration Tests

The tests in the Lockport lock can be used in another way to demonstrate that the formulas are correctly set up. The lock was 137 by 22 by 26 ft. deep. It had a diffuser plate area equal to 12 per cent of the lock area. The plates were at both ends, equally divided, so that the diffused air overturned the water in the lock, toward and away from the mid point. For such conditions, Eq. 7 for the plate area of 10 per cent should apply very closely. The diffusers used, based on recent tests on the same type of plate, should have produced an effective bubble diameter of about 0.09 in. Therefore, Eq. 8, which is a converted form of Eq. 7, applicable to 26 ft. depth and 0.09 in. bubbles, can be used for conditions such as obtained in the lock. Eq. 8 can be converted to the form:

$$K = 0.46R^{0.79}(1.024)^{T} \ldots . (14)$$

in which K is the oxygen absorption in p.p.m. per hour per p.p.m. oxygen deficiency at 0.35 depth, occurring with tap water ($C = 1.0$). The actual value of K obtained in the lock divided by the value for tap water under the same conditions of aeration is the oxygen absorption coefficient, C. Table VII gives the results of typical tests in the lock and the computed values of C.

For the tests shown, the oxygen absorption coefficient, C, averaged 0.44 in 1924, and 0.22 in 1925. In 1924, the water entering the lock for aeration contained about 1.0 p.p.m. of D.O. and about 21 p.p.m. of 20-day B.O.D. In 1925 the D.O. of the entering water was zero and the 20-day B.O.D. about 33 p.p.m. The reduced value of the coefficient in the second year was due to the anaerobic condition of the polluted water.

Tests, to be described later, made by the writer in 1952 and 1953 on settled sewage in the 10-in. depth tank showed about the same relative differ-

ence in the values of the oxygen absorption coefficient for aerobic and anaerobic conditions. The coefficient values, however, were about 20 per cent lower for settled sewage than those obtained for the polluted water in the lock. This difference seems reasonable and could be attributed to the higher degree of pollution in the sewage. Therefore, these two sets of results tend to show that the formulas are reliable and applicable over a wide range of depth.

Air Bubble Diameter

The diameters of bubbles of air diffused from new porous plates were measured in the Sanitary District in 1935. Beck (12) was able to do this by photographing them against a background of cross-section paper which had 20 divisions per inch. The bubbles were measured for about 15 different porous plates (12-in. square) at air diffusion rates of 1 and 4 c.f.m. The average diameters of the bubbles from three of these plates are given in Table VIII. Also given are the absorption rates, computed by formula for these diameters, and the actual rates as measured on clean unused plates of the same kind as used in Beck's tests.

The oxygen absorption rates were measured in the test tank with 3-ft. depth of 72° F. sulfite solution on the diffuser plate. The results are converted to water. Barometric pressure was about 29.4 in. Hg. The diffusion rate was 1 c.f.m. per plate, equivalent to 31.8 c.f.m. per 1,000 cu. ft. of solution. Eq. 7 was used for the computation.

The bubble sizes as determined by Beck were used to check the oxygen absorption formulas developed herein. It was on the basis of such a check that the formula for the diffuser plate area of 10 per cent was revised to give 5 per cent higher oxygen absorption for 1-ft. depth.

The measurements of bubbles made by Beck indicate a small increase occurs in their diameter with an increase in the rate of air diffusion. For the 15 plates tested, the diameters averaged about 5 per cent larger at 4 than at 1 c.f.m. The 9 plates with the larger bubbles (over 0.08 in.) had diameters averaging about 2.5 per cent larger at the higher rate.

The oxygen absorption formulas were computed on the basis that air bubbles remain unchanged in average size as the rate of diffusion increases. A small change (such as 2.5 to 5 per cent) in bubble diameter would mean only 2 to 3 per cent error in results as computed by the formula. There-

TABLE VII.—Results of Lockport Aeration Tests

Test	Air Rate, R (c.f.m./1,000 cu. ft.	Water Temp., T (°C.)	Oxygen Absorption, K (p.p.m./hr.)		Oxygen Absorption Coefficient, C
			Tap Water[1]	Test Results	
8/23/24	25.3	23	9.17	3.03	0.33
8/26/24	27.4	25	11.10	5.38	0.49
9/ 3/24	10.1	20	4.50	1.95	0.43
10/2/24	23.4	16	8.00	4.00	0.50
10/2/24	12.1	17	4.75	2.45	0.52
10/7/24	11.6	20	5.00	2.19	0.44
10/7/24	12.0	17	4.82	1.95	0.40
7/21/25	11.1	23.5	5.25	1.02	0.20
7/22/25	14.2	22.5	5.48	1.19	0.22
7/22/25	19.3	23.0	8.00	1.95	0.24
7/24/25	26.0	23.0	10.5	2.38	0.23

[1] Eq. 14.

TABLE VIII.—Effect of Air Bubble Diameter on Oxygen Absorption

Plate	Bubble Diameter (in.)[1]		Oxygen Absorption p.p.m./hr. (3 feet depth on diffuser plate)		
	1 c.f.m.	4 c.f.m.	Computed (Bubble dia. at 1 c.f.m.)	By Test	
				Plates Tested	Avg. Rate
N33	0.086	0.087	51.2	2	52.7
C40	0.077	0.081	55.0	5	53.8
F24	0.076	0.086	55.8	1	58.5
Avg.	0.080	0.085	54.0		55.0

[1] Measurements by Beck (12).

fore, the use of an unchanging bubble size in the derivation of the formulas is for all practical purposes a proper procedure, because the resulting errors are minor.

Oxygen Absorption Rating of Air Diffuser Plates

Air diffuser plates were compared by the writer (14) on the basis of oxygen absorption produced. Tests for this purpose were made in the 3-ft. depth tank using sulfite solution. Air was applied at a rate of 1 c.f.m., equivalent to 31.8 c.f.m. per 1,000 cu. ft. of liquid. The solution was maintained at a constant temperature of 72° F. The plates were soaked in water for several hours prior to testing. The oxygen absorption rate in p.p.m. per hour was designated as the rating of a plate. A part of the results converted to water as summarized in Table IX. Also indicated therein are the air bubble sizes as computed by Eq. 7 from the conditions and the results of the tests.

Air diffuser plates are graded according to their capacity to pass air when dry, a characteristic called "permeability," which is defined as the number of cubic feet of free air at 70° F. passing 1 sq. ft. of plate at a pressure loss of 2 in. of water. The permeability rating, however, is not a measure of the capacity of a plate to produce oxygen absorption, as may be seen by an inspection of Table IX. On the other hand, the oxygen absorption rating is a definite measure of plate efficiency and therefore serves as a measure of air bubble size. The average bubble size is an indication of the average pore size, which is important information in regard to clogging characteristics of plates.

The oxygen absorption ratings of used plates were different from those that obtained when new. This is to be expected, as plates in service soon become dirty and coated. It is of interest to note that in the Sanitary District, after a period of service, plates of small grain and pore size lose in efficiency, whereas those of larger grain and pore size, improve. After several years of service, plates tested for oxygen absorption rating (that is, after being thoroughly soaked) usually produced an effective bubble of about 0.1-in. average diameter, in the oxygen absorption rating test.

In rating plates for oxygen absorption, they were thoroughly soaked before being tested. In operation, however, the plates may be dry or wet internally, depending on atmospheric conditions and sewage temperatures. The oxygen absorption rates for plates dry internally were lower than when soaked prior to testing. This is illustrated in Figure 7 by the tests for the 10-in. ($H = 0.83$ ft.) diffuser depth on September 18, 1951, and April 8,

TABLE IX.—Oxygen Absorption for Plates at 3-Ft. Depth in Circulating Type Tank

(Tests Made in Sulfite Solution; Results Converted to Water)

Plate[1]		Number Tested	Average Perm.	Oxygen Absorp. (p.p.m./hr.)[2]	Bubble Diam. (in.)[3]
Type	Nominal Perm.				
(*a*) New (Clean Unused) Plates					
C	40	5	39.9	53.8	0.080
C	60	2	58.0	47.2	0.097
C	80	3	83.5	40.8	0.118
E	30	3	31.2	58.8	0.070
E	70	3	72.6	51.1	0.086
E	80	10	80.4	33.7	0.156
F	24	1	24.0	58.5	0.071
F	46	1	46.0	37.8	0.137
N	33	2	33.0	52.7	0.083
N	40	4	43.1	46.7	0.098
N	80	4	80.7	41.3	0.117
N	120	3	119.3	31.8	0.169
(*b*) Used Plates					
C	40	6	40±	46.2	0.099
E	80	2	76.0	36.7	0.138
F	16	2	16±	49.4	0.091
N	80	3	40±	47.2	0.097

[1] 12 in. by 12 in.
[2] 93.5 per cent of ratings in sulfite solution.
[3] Computed by Eq. 7.

1952. The same diffuser was used in both instances. In the first test, the diffuser was started up after standing dry for some time. In the second test, however, the diffuser was submerged for several days prior to testing. It is to be noted that this treatment reduced the bubble size by about 25 per cent and increased the absorption rate about 20 per cent. As long as the diffusers were kept thoroughly wet, test results could be duplicated. When not thoroughly soaked prior to testing, variations in results occurred, possibly due to variations in the internal wetting of the diffuser.

For new fine grain plates producing a bubble size of 0.1 in. or less, when soaked, the absorption was 5 to 10 per cent more than that in the dry condition. For new coarser plates producing a bubble size of 0.12 in. and over, when soaked, the absorption was as much as 20 per cent more than that in the dry condition. Used plates also showed a variation between the wet and dry condition—the larger the grain size, the more the difference.

The oxygen absorption ratings of plates at the 3-ft. depth can be used by means of the formulas to compute the relative efficiency of these same plates when initially put into service in tanks of any other depth. This can be done by using the rating to compute the bubble size and using this in the formulas, for the depth and diffuser plate area at which the plates are to be operated. Although the finer grain plates seem to lose in efficiency with service, whereas the coarser grain plates improve, it is quite probable that the plate producing the better diffusion initially always remains the better from that one particular standpoint.

It is quite probable that diffuser plates when first put into service produce bubbles of diameters larger than those occurring in the rating test. This is probably due to the fact that plates in aeration tanks are normally operated at higher rates than that used for the rating, thus tending to produce dry interiors by blowing out any condensation that might occur there. Under certain weather conditions, however, moisture might be present for considerable periods of time. Progressive clogging means the air must move through the plate openings at higher and higher velocities, causing it to break into increasingly larger bubbles. On the other hand, the reduction of the size of the openings due to clogging tends to reduce the bubble size. The former effect seems to be the predominant one in plates with fine grains, the latter in plates with larger grains.

The lower the oxygen absorption rating of a new plate, the larger its pores and the longer its service (15)

before pressure losses become excessive due to clogging from dust particles in the air. The best plate for use in any particular plant is that which will result in the lowest overall cost for air for sewage treatment. Installation of plates of quite low rating in oxygen absorption may result in excessively high air consumption for a period of years, more than offsetting the savings due to longer service, low pressure losses, and low costs for air filtering. Installation of plates of quite high oxygen absorption rating may result in short service and high pressure losses more than offsetting the advantages of the initially high efficiency in air diffusion.

On the other hand, future developments may show economy in the use of plates of quite high oxygen absorption rating if it can be demonstrated that the initial efficiency can be retained and long service assured at low pressure losses by providing air filters of an exceptionally high degree of efficiency. These are only a few of the problems involved in the selection of the air diffusers for any plants, which can be met with greater success when more data become available on the oxygen absorption ratings of new and used plates as related to the peculiarities of various sewage treatment plants.

Oxygen Absorption in the Activated Sludge Process

Pollution in water retards the rate (16)(17) at which oxygen enters solution. Oxygen absorption rates are low in sewage, but when it is brought into contact with activated sludge considerable improvement takes place. Data pertaining to this phenomenon were obtained by experiments with sewage and activated sludge.

The arrangement at the North Side plant was such that it was possible to pump settled sewage and return activated sludge to the 10- and 20-in. depth tanks in the laboratory. Thus, tests could be made in these small tanks on sewage the same as that entering the aeration tanks, and also on a mixture of the same sewage and activated sludge as being aerated in the activated sludge process. By timing the travel of the mixed liquor in the aeration tanks, samples could be taken there after treatment corresponding to that obtaining in a test in a small tank in the laboratory.

The oxygen absorption coefficient, designated as C in Eqs. 6 and 7, is the ratio of any particular oxygen absorption rate to that obtaining for clean water under the same conditions of aeration. The values of this coefficient for sewage and mixed liquor were measured in the 10-in. tank. For sewage this was easily done by aerating the sewage in the tank, sampling periodically for D.O., and solving for K (oxygen absorption in p.p.m. per hour per p.p.m. deficiency) in accordance with Eq. 10. This K divided by its value for clean water, under the same conditions of aeration, gave the value of the absorption coefficient C.

For mixed liquor the procedure was the same, but first it was necessary to remove the oxygen demand of the sludge before determining K. This was done by settling out the sludge and then transferring the supernatant to the 10-in. tank for separate aeration. Aeration of the mixed liquor after the destruction of life in the sludge by means of acid or copper sulfate was tried, but this gave very low values of K, obviously in error. Apparently, destroying the life in the sludge caused it to release substances retarding oxygen absorption.

The results of two typical experiments on the oxygen absorption by mixed liquor are shown graphically in Figures 8 and 9. In tests of this type, the 20-in. tank was used for aerating the mixed liquor. The oxygen absorption coefficient at the be-

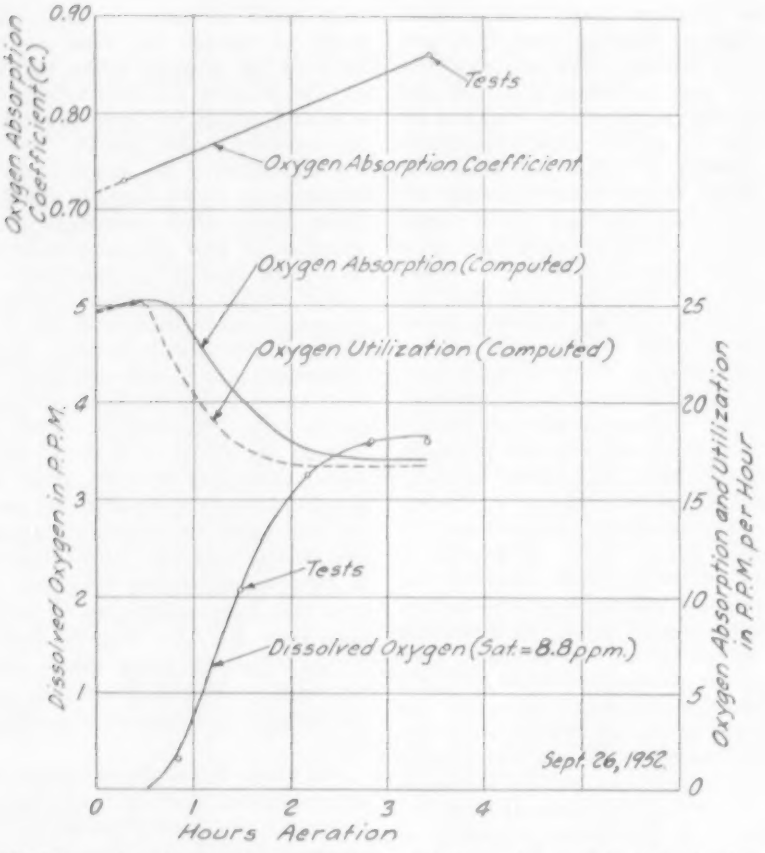


FIGURE 8.—Aeration of mixture of activated sludge and sewage in 20-in. depth tank; temperature 21.3° C., barometer 722 mm., air 31.5 c.f.m. per 1,000 cu. ft., oxygen absorption for tap water 3.9 p.p.m. per hr. per p.p.m. oxygen deficiency.

ginning of the aeration period was determined by aerating a mixture of sewage and return sludge for 5 to 15 min., turning off the air, settling out the sludge, and decanting the supernatant into the 10-in. tank for a determination of the value of the coefficient.

A new mixture of sewage and return sludge of the same ratio used previously was immediately put into the 20-in. tank and the aeration period of the test started, at the end of which the supernatant was again decanted into the smaller tank for a determination of the absorption coefficient. During the test D.O. determinations were made periodically on the mixed liquor. From the oxygen deficiencies, the values of the oxygen absorption coefficient, and the known absorption rates for clean water in the 20-in. tank, the oxygen absorption rate for the mixed liquor was computed and plotted in relation to time. Taking into consideration variations in D.O., it was then possible to compute and plot the curve of oxygen utilization for the sludge. The mixture was sampled for suspended sol-

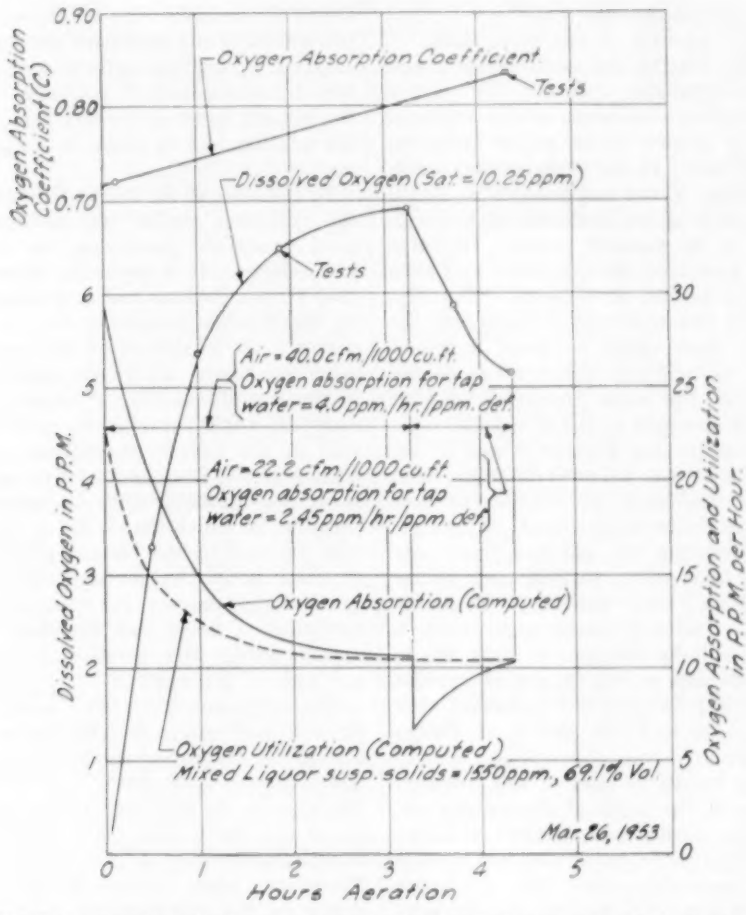


FIGURE 9.—Aeration of mixture of activated sludge and sewage in 20-in. depth tank; mixed liquor temperature 13.8° C., barometer 751 mm.

ids in order to obtain the oxygen demand per unit of solids.

The oxygen utilization rate was unaffected by changes in agitation and D.O. content of the mixed liquor. This is illustrated in Figure 9 by the change in the rate of air application from 40 to 22.5 c.f.m. per 1,000 cu. ft. without any apparent effect on the rate at which the sludge used up oxygen.

The validity of the test as a method of measuring oxygen utilization rate of sludge was demonstrated by running simultaneous tests at 20° C. on mixed liquor in the 20-in. tank and on samples of the same liquor in bottle tests. The latter method consisted of diluting the mixed liquor with distilled water in 1-l. bottles and measuring the dissolved oxygen used by known weights of activated sludge solids in 1-, 2-, 3-, and 4-hr. periods. The bottles were attached to a 4-ft. diameter vertical wheel which revolved at 2 p.p.m. Each bottle contained 60 grains of sand to insure agitation. The results of this method closely checked

the oxygen demand rates per unit of solids obtained in the 20-in. tank.

The tests in the small experimental tanks provided data on the oxygen absorption coefficient in the activated sludge process under actual operating conditions. In the experimental setup, however, it was not possible to obtain the value of the coefficient at intervals during the aeration period. Its value was measured after a short and then a long period of aeration. The first period was kept very short so that the 20-in. tank could be filled a second time with mixed liquor of as nearly possible the same character as that which obtained in the first run.

In preparing Figures 8 and 9, the coefficient was assumed to improve in value uniformly in relation to time during the aeration period. Where the improvement was not too great, any error involved in making such an assumption was probably relatively small. However, much more research work will be required if data are to be provided on the oxygen absorption coefficient as related to aeration time and rates and the extent of sludge oxidation.

The results of part of the measurements of the value of the oxygen absorption coefficient are shown in Table X. It is to be noted that for sewage still containing some D.O. the value varied from 0.27 to 0.46, but for sewage in which anaerobic conditions had been set up the variation was from 0.16 to 0.19. The initial values of the coefficient in the activated sludge process at the North Side plant ranged from 0.68 to 0.73 and were increased by aeration to values ranging from 0.76 to 1.00.

Activated sludge has highly effective adsorptive and flocculating properties, so that sewage intimately exposed to it is rapidly freed from dissolved and suspended impurities. This is reflected by the immediate rise in the value of the oxygen absorption coefficient when activated sludge is added to sewage. The continued improvement in the coefficient during the aeration period also reflects the additional transference of pollution from the sewage to the activated sludge as the mixture travels along in the process.

In the tests at the North Side plant, the activated sludge was always in good condition, producing an excellent effluent. It is probable, however, that if the process had lost some of its clarification properties due to the presence of substances in the sewage inhibitive to the life of the organisms in the sludge, the rate of oxygen absorption would have been retarded; that is, the oxygen absorption coefficient C would have had a lower value. It is also probable that in modified aeration, in which the sludge is not so well oxidized or the effluent produced as good as in the conventional activated sludge process, the value of the coefficient is lower and therefore the oxygen going into solution is lower per unit of air applied.

The oxygen utilization rates of the activated sludge and the values of the oxygen absorption coefficient of the mixed liquor must have been nearly the same in the activated sludge process of the North Side plant as in the experimental tank in the laboratory. Therefore, when mixed liquor was drawn to the experimental tank and aeration started, the mixed liquor from which the sample was taken was followed as it traveled through one of the large 15-ft. depth tanks of the plant and D.O. determinations were made from time to time. From the D.O. variation in relation to time in the mixed liquor as it moved through this tank and the corresponding variations in oxygen utilization and oxygen absorption coefficient which must have obtained, as measured in relation to time in the experimental tank, it was possible to compute the oxygen absorption obtaining in the activated sludge process of the North Side plant.

TABLE X.—Oxygen Absorption Coefficients For Sewage and Mixed Liquor

Date	Test No.	Time Started (AM)	Sample	Temp. (°F.)	Susp. Solids (p.p.m.)	D.O. in Sewage (p.p.m.)	Aeration[1] (min.)	Oxygen Absorp. Coef., C
8/11/52 (Monday)	1	8:45	Sewage	70	—	1.5	0	0.35
		8:45	Mixed liq.	70	1,400[2]	1.5	10	0.76
	2	10:25	Sewage	68	—	0.0	0	0.18
		10:25	Mixed liq.	68	1,400[2]	0.0	42	0.68
	3	11:45	Sewage	68	—	0.0	0	0.16
		11:45	Mixed liq.	68	1,400[2]	0.0	180	0.76
9/26/52 (Tuesday)	1	10:10	Sewage	70	—	2.0	0	0.37
		10:10	Mixed liq.	70	2,200[2]	2.0	15	0.73
	2	11:25	Sewage	70	—	0.5	0	0.27
		11:25	Mixed liq.	70	2,200[2]	0.5	207	0.86
2/13/53 (Friday)	1	9:20	Sewage	52	—	0.8	0	0.36
		9:20	Mixed liq.	52	1,300[2]	0.8	5	0.70
	2	11:00	Sewage	52	—	5.0	0	0.46
		11:00	Mixed liq.	52	1,300[2]	5.0	219	0.80
3/4/53 (Wednesday)	1	9:55	Mixed liq.	50	1,620[3]	Present	5	0.71
	2	10:40	Mixed liq.	51	1,620[3]	Present	180	0.82
3/26/53 (Thursday)	1	9:30	Mixed liq.	57	1,500[3]	Present	5	0.73
	2	10:00	Mixed liq.	57	1,500[3]	Present	260	0.84
4/1/53 (Wednesday)	1	10:15	Mixed liq.	51	2,100[3]	Present	192	0.91
9/17/53 (Thursday)	1	9:25	Sewage	70	—	0.0	0	0.18
	2	9:25	Mixed liq.	70	1,450[3]	0.0	10	0.68
	3	10:15	Mixed liq.	70	1,450[3]	0.0	265	0.97
9/18/53 (Friday)	1	9:30	Sewage	71	—	0.0	0	0.19
	2	9:30	Mixed liq.	71	1,620[3]	0.0	10	0.72
	3	10:10	Mixed liq.	71	1,620[3]	0.0	260	1.00

[1] Prior to determination of oxygen absorption coefficient.
[2] Estimated on basis of per cent return sludge.
[3] By analysis.

The diffuser plates in the aeration tanks of the plant had been in service about two years. In four out of five tests made, the oxygen absorption rates as determined by the method described were about 88 per cent of those computed by the applicable formula (Eq. 6) using the bubble size that obtained for these plates, when new, in the oxygen absorption rating test. In the fifth test, in which condensation was probably present in the plates, the absorption obtained by the method described corresponded with that computed by the formula. These results indicated that the diffusers in the process, when dry internally, were producing bubbles about 20 per cent larger than those obtained in the rating test, in which the plates were always thoroughly soaked before being tested. These larger bubbles seem entirely reasonable, considering the results of tests made in the rating tank when plates were not subjected to prior soaking.

The bubble size indicated by the procedure to obtain in the activated sludge process was checked approximately. A 1-in. graduated glass tube,

closed on one end and bushed down to ½-in. at the other, was filled with water and inverted in the aeration tank with the open end several inches below the surface. Trapped air bubbles rose in the tube, displacing the water. From the counted number required to displace a certain volume of water, the average diameter of the bubbles leaving the diffusers could be computed, taking into consideration, of course, the pressure difference at the diffuser and in the 1-in. tube. This device was also used to measure bubble sizes in the experimental tanks.

Although the bubble count was only approximate, the fact that sphere volume varies as the cube of the diameter tended to reduce errors. A 20 per cent error in count meant only a 6 per cent error in bubble diameter. Dividing a volume of air by the number of bubbles to get the average diameter involved in some error, since the diffused air bubbles are made up of various diameters. These tests, however, were sufficiently accurate to indicate the relative bubble sizes in various tanks and to lend assurance to the conclusion that the formulas closely reflect the effect of the bubble diameter on the rate of oxygen absorption in spiral flow aeration tanks.

Summary of Experimental Work

The experimental work described herein was done in order to check the reliability of the oxygen absorption formulas derived by the author. Many factors influence the rate at which oxygen enters solution in the activated sludge process. Therefore, the tests were made to measure the effect of these factors, one at a time, insofar as it was practical to do so. This served as a check on the setup of the formulas. Measurements of oxygen absorption rates of water and activated sludge when all factors were reasonably well known served as overall checks in the formulas.

In view of the results of tests presented herein, the formulas are believed to be reasonably accurate. Future experimental work may determine certain modifications that will result in greater accuracy. Until that time, however, the formulas as presented will probably serve as the best method for computing the oxygen absorption rates in spiral flow aeration tanks.

ATLANTIC CITY ON DAYLIGHT TIME

All those who attend the Annual Meeting of the Federation in Atlantic City, October 10–13, 1955, should make their travel plans on the basis of Eastern Daylight time at the Convention. Atlantic City, with many other Eastern communities, continues daylight time until the last Sunday in October. Accordingly, the whole Federation program including technical sessions, the social events and the Board of Control meetings are scheduled on this basis.

IT IS NOT TOO LATE TO MAKE YOUR FINAL PLANS TO ATTEND!

Industrial Wastes

TREATMENT OF WASTES FROM VISCOSE PROCESSES *

By W. J. Eldridge

Engineer, E. I. duPont de Nemours and Company, Inc., Old Hickory, Tenn.

To solve any industrial waste problem, it is first necessary to determine all factors involved, then reduce the waste to a minimum at the source by recovery or change in process before resorting to treatment (1)(2). Treatment is usually costly and gives no return on the investment. At the Old Hickory Works of E. I. du Pont de Nemours and Company the cost of waste disposal facilities consisting of a retention basin, diffusion piping and ash disposal facilities will approximate $750,000.

It is very rare that the experience at one industrial plant in solving a stream pollution problem can be applied directly to another industrial plant even though the plants have the same basic process. This is due to variations in process and geographical location.

The viscose processes, which are all based on the dissolving and regeneration of cellulose, are a good illustration. Textile yarn, tire cord rayon, spun rayon, cellophane, cellulose sponges and cellulose caps and bands are all made from viscose. Each of these can be subdivided into several variations. For example, in textile rayons, there are bright, semi-dull, and dull rayon, Fiber "E", thick and thin, nubby yarn, textile cordura and other textile rayons. Each of these has a variation in process that may give an entirely different industrial waste problem.

To illustrate further, the du Pont Company has plants at five locations using the cellulose viscose process. At two of these plants there is no stream pollution problem because of their geographical location on large rivers. At another location acid and B.O.D. are the industrial waste problems. There it is necessary to neutralize partially the acid waste and to use close control to keep the B.O.D. within the limits set by the state stream pollution control board. Another location has the problem of B.O.D. reduction but the oxygen demand is caused by inorganic rather than organic materials. At this location, alkaline chlorination is used to reduce the B.O.D.

At Old Hickory, Tenn. (Figure 1), the problems are reduction of B.O.D., settleable and floating solids, and the need of blending the wastes. By recovery, changes in process and constant vigilance the B.O.D. of the waste has been maintained at a level that will not reduce the dissolved oxygen in the Cumberland River below acceptable limits. The purpose of the waste retention basin and waste diffusion piping is to remove the settleable and floating solids, blend the wastes and discharge the effluent so that it will mix with the cold water in Old Hickory Lake. Also, the B.O.D. of the waste is expected to be reduced.

* Presented at 1954 Annual Meeting, Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.; Nashville, Tenn.; Sept. 20–22, 1954.

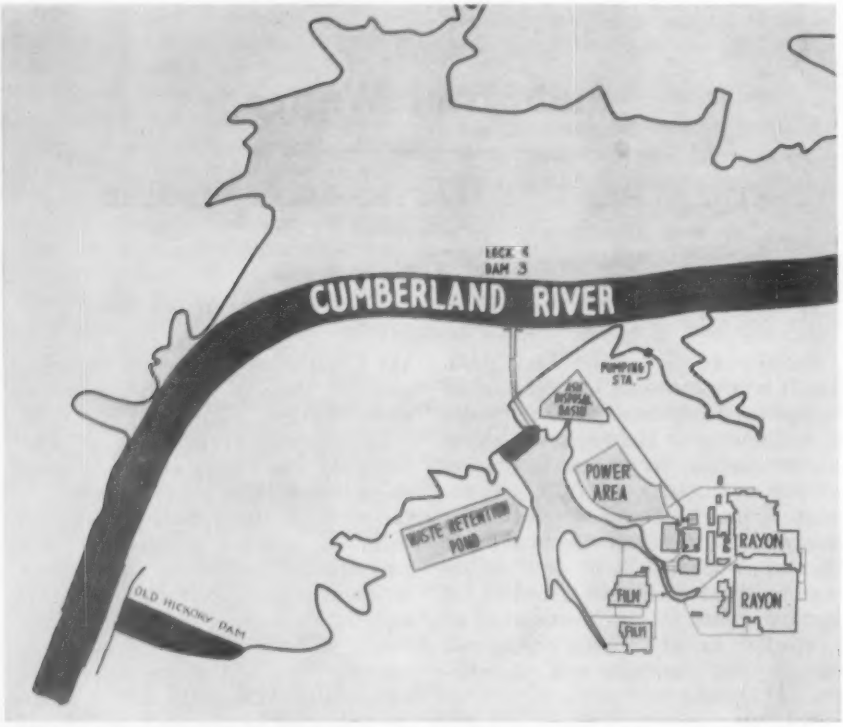
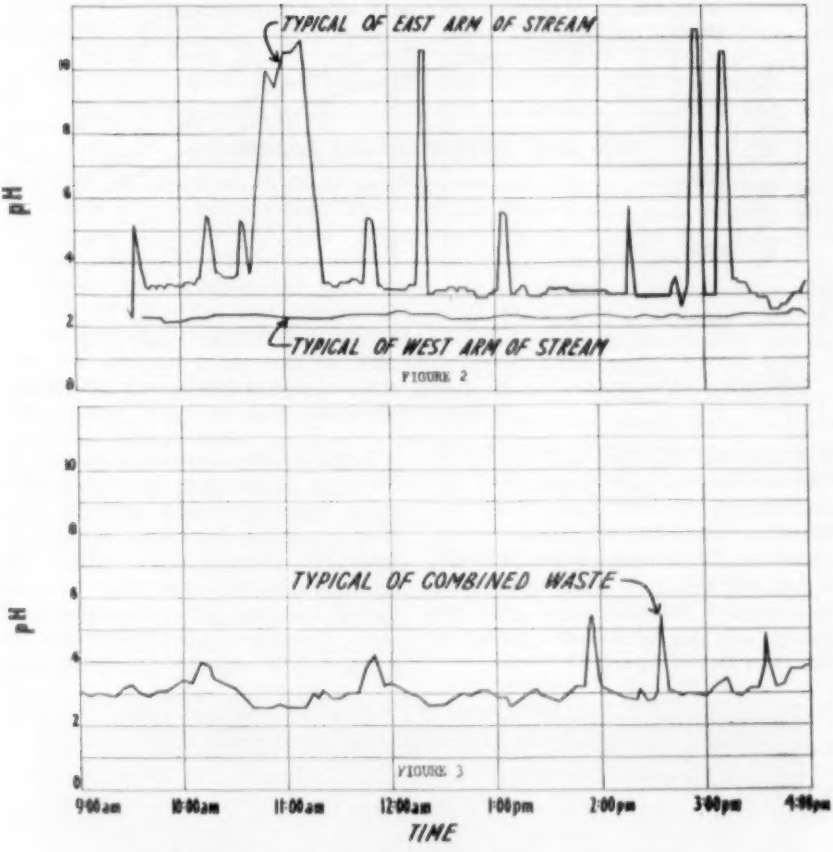


FIGURE 1.—Cumberland River and the Old Hickory manufacturing works of E. I. du Pont de Nemours and Company. Outlined area will be submerged.

The wastes from the Old Hickory plants discharge into two streams which converge before entering the river. Figures 2 and 3 give the results of 7-hr. tests of the pH of the wastes in these two streams and the waste in the combined stream. These tests were carried out on different days and, therefore, cannot be compared directly. Figure 2 shows that the waste in the east arm of the stream is alkaline at times while that in the west arm is consistently acid. Figure 3 shows that the pH of the combined waste varies over a much smaller range than in the east arm and is normally acid, thus promoting better settling of the suspended solids. These observations together with those of color and turbidity of the waste indicated the desirability of blending the two wastes. The acidity of this combined waste is not sufficient to effect adversely the pH and alkalinity of the river water after mixing.

To form the waste retention basin a dam is being constructed across the ravine in which the combined trade waste stream flows. This dam will have a length at the crest of 630 ft., an axis length at the base of 240 ft. and an over-all height at the center of 60 ft. The water level in the basin formed will be approximately 25 ft. above the normal level of the lake that will be formed behind Old Hickory Dam also under construction. Approximately 120,000 cu. yd. of earth will be moved to form a basin covering approximately 19.2 acres.

Mixing of the effluent of the waste retention basin with the waters of Old



FIGURES 2 and 3.—The pH of the receiving streams.

Hickory Lake will present a problem. Experience with the T.V.A. lakes indicates that a relative density difference as small as 0.0006 causes water to stratify. The difference in the relative density of the waste from the Old Hickory plant and the Cumberland River water is much greater than this (Figure 4).

The relative density of the waste at 75 ° F. is greater than the Cumberland River water at the same temperature. This density is 0.9991 compared to 0.9974 for the river. The normal temperature of the waste is 100° F. or about 25° F. higher than the river water temperature of 75° F. At this temperature the waste would have a relative density of 0.9950 that would make it lighter than the river water. The density difference of 0.0024 would cause the waste to stratify on top of the water and be subject to the wind. This was verified by observations and by following the waste flow in the river by a conductivity meter.

It was concluded that the waste should not be discharged to the lake adjacent to the waste retention basin but should be diffused into the colder water that flows down the present river channel. This will be approximately 46 ft. below the normal lake level.

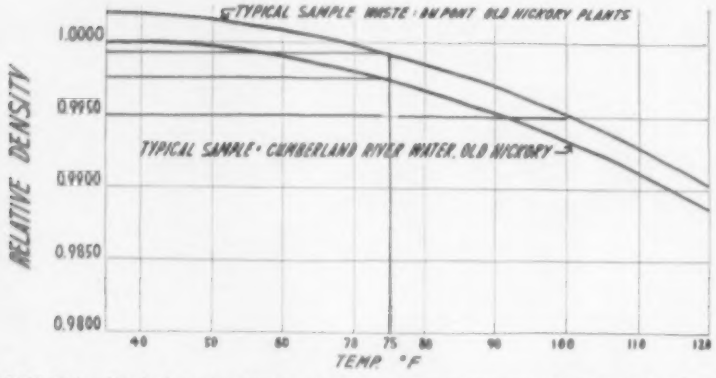


FIGURE 4.—Variations in relative density of the waste and Cumberland River with temperature changes.

To accomplish this two 36-in. diameter vitrified clay pipes, each approximately 1,800-ft. long, were laid from the waste retention basin to the abutment of the existing low Dam No. 3 that will remain in place but will be inundated. The discharge lines are secured to this abutment parallel to the river flow (Figure 5).

Normally, the waste will flow through the pipe discharging below the dam at an angle downward through three 36-in. by 36-in. by 12-in. lateral tees. After Old Hickory Lake is filled, the colder water will flow down the old stream bed and over the submerged dam. Therefore, it is believed that the waste will be adequately mixed with

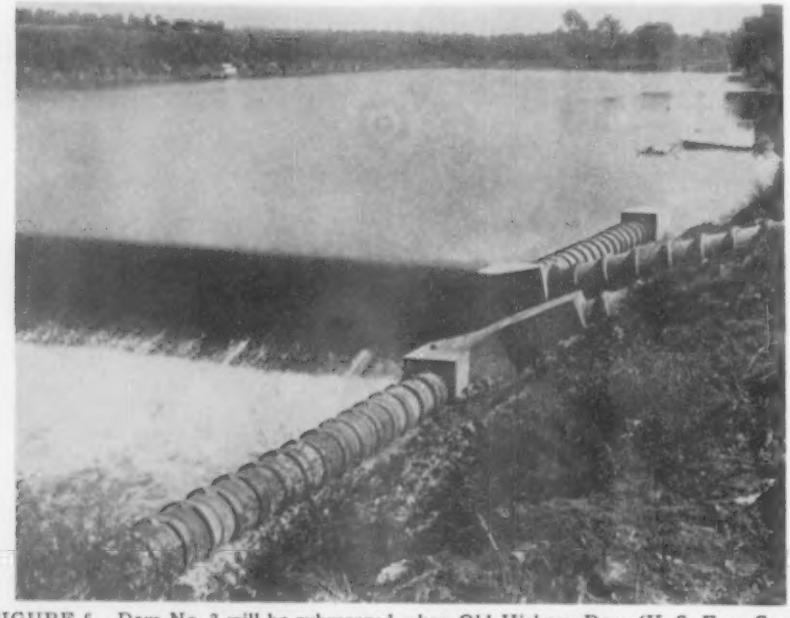


FIGURE 5.—Dam No. 3 will be submerged when Old Hickory Dam (U. S. Eng. Corps) is filled. Pipes are 36-in. waste discharge lines.

the colder water to prevent it from stratifying and rising to the surface.

The second 36-in. pipe is provided to take care of run-off due to rainfall. It will discharge above the dam through three 36-in. by 36-in. by 18-in. tees. There is also a spillway to provide for abnormal rainfall runoff in excess of the amount that can be discharged through the two 36-in. pipes.

Previously, facilities had been installed for pumping and settling the ashes from the power houses. Because the ash settling basin will be inundated by Old Hickory Lake, a new ash settling basin was formed by constructing dikes around an area covering approximately 6 acres and by providing a suitable overflow.

In addition, a trickling filter sewage treatment plant was constructed by the du Pont Company in 1949 at a cost of $232,000 to treat sanitary wastes from the community of Old Hickory and a large portion of the manufacturing plant. This sewage treatment plant is operated by the Old Hickory Utility District.

The improvement that will result from the operation of the waste treatment facilities should prevent any undesirable effect on the waters of Old Hickory Lake or the river below the lake. Specifically, these facilities will adequately treat all sanitary wastes, practically eliminate settleable and floating solids, blend the industrial wastes, reduce the biochemical oxygen demand of the wastes to an acceptable level and diffuse the remaining liquid waste from the plant in the cold water that will flow down the channel of the Cumberland River.

In conclusion, it should be emphasized that it is very rare that the waste treatment experience at one manufacturing plant can be applied directly to another. This is invariably true even though the same basic process is involved or the same general type of product is manufactured. Variations in process or geographical location are two important factors leading to this conclusion.

References

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2. "Organization and Method for Investigating Wastes in Relation to Water Pollution." In "Water Pollution Abatement Manual W–1," Manuf. Chemists Assn., Washington, D. C.

HOTEL ROOMS PLENTIFUL IN ATLANTIC CITY

The site of the Annual Meeting of the Federation this year, Atlantic City, October 10–13, is unique in that there is an abundance of hotel rooms. While many reservations have been made at the headquarters hotel, the Ambassador, rooms are still available there as well as in other fine hotels on the Boardwalk. In contrast to the usual situation of standing room only, the convention city offers ample accommodations for those who have been unable to make reservations and final plans previously. Even if your plans do not materialize until the last minute, it is most unlikely that Atlantic City will disappoint you for sleeping space!

TREATMENT OF LITHOGRAPHIC WASTES*

By John J. Baffa and Harold E. Orford

Consulting Engineer, New York City and Chairman, Department of Sanitation, New Jersey Agricultural Experiment Station, New Brunswick, N. J.

The design of waste treatment facilities for wastes originating from a lithographic plant in Nassau County, New York presented an unusual challenge. Absence of a community sewer system together with limiting topographic features made it necessary to discharge the treated wastes to the ground water aquifer. Ground water in the area constitutes the local water supply.

Even if municipal sewers were available the existing regulations prohibit the discharge of raw wastes having an analysis typical of lithographic wastes. The wastes under consideration had an average hexavalent chromium content of 13 p.p.m. Accordingly, pretreatment would be the minimum requirement when sewers are constructed. Treatment requirements include the reduction of hexavalent chromium and other metallic ions. In addition, organic materials had to be removed that would clog the soil and prevent satisfactory disposal by leaching wells.

Quality of Wastes

Wastes from lithographic facilities contain many substances in varying concentrations. Calcium, magnesium, zinc, cupric and iron salts are present together with those containing hexavalent chromium. Hexavalent chromium content results from waste solutions used for preparing the surface of lithographic plates. The B.O.D. is due to albumin, gum, casein, alcohols, and organic acids. Gum arabic, a major constituent of the wastes, is present in an average concentration of about 5,000 p.p.m. In addition, hydrochloric acid, organic dyes and shellac are found in the wastes.

In Table I are shown the analyses of two lithographic wastes. Waste A results from the manufacture of plate sensitizing solutions, lacquers and chemicals used in lithographic processes, while waste B is from a lithographic plant.

Laboratory Studies

These wastes posed unusual problems because of their composition and the requirement that the effluent was to be discharged into the ground. Before any of the design problems could be considered, it was necessary to undertake a laboratory investigation to determine the waste characteristics and develop a treatment method. The use of a pilot unit to work out treatment problems was considered prohibitively expensive. Thus, it fell upon the laboratory investigation to obtain relatively accurate design information. The laboratory development of the treatment process described is limited to the lithographic plant waste.

Following are the waste treatment problems that the laboratory investigation was designed to solve together with the treatment methods that appeared worthy of investigation:

1. Removal of hexavalent chromium and possibly other toxic metals by reduction of the chromium with ferrous sulfate and precipitation as the hydroxide at pH 8.5 to 9 using lime.

* Presented at 1955 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York City, N. Y.; Jan. 20–21, 1955.

2. Removal of suspended and colloidal solids by means of chemical treatment with ferric chloride and lime to precipitate the floc at pH 8.5 to 9; or with ferrous sulfate and lime.

3. Removal of color with activated carbon or chlorine.

4. Removal of B.O.D. (principally solvents) through the use of excess plain aeration or chemical coagulation.

The development of the treatment process was divided into several steps. The first problem was the reduction and removal of chromium. Ferrous sulfate was selected as the reducing agent because it was believed the excess ferrous iron used and oxidized by the chromate would aid in the chemical coagulation. Also, the end products are non-toxic. The recommended amount of ferrous sulfate, or approximately 32 p.p.m. of copperas for each p.p.m. of chromium, was sufficient to reduce the chromium. This is roughly 50 per cent more than theoretically required; actually a 60 per cent excess was used in the laboratory tests.

After a one hour reaction with the copperas, lime was added to raise the pH between 8.5 and 9.0. This precipitated the chromium and the remaining ferrous iron which it was hoped would also precipitate the suspended matter. Actually, the amount of ferrous iron was insufficient to do this and additional iron was found necessary. Because of its greater efficiency ferric iron in the form of ferric chloride was used for the additional coagulant. The ferrous and ferric iron salts were added together; after a reaction period lime was added to effect the required precipitation of chromium and organic suspended solids. The precipitated solids settled well and the sludge amounted to 10 per cent by volume, after one hour settling. Indications were that with a full scale plant the sludge volume could be expected to be 4 to 5 per cent of the waste treated.

TABLE I.—Analyses of Lithographic Wastes

Waste Characteristics	Waste A (p.p.m.)	Waste B (p.p.m.)
pH	6.6	6.75
Total Solids	6,600	1,160
Fixed	3,900	410
Volatile	2,700	750
Suspended Solids	200	265
Fixed	0	50
Volatile	200	215
Dissolved and Coll. Sol.	6,400	895
B.O.D. (5-day 20°C.)	250	965
Hexavalent Chromium	0	13
Color	Deep Blue	Deep Green

After sedimentation the supernatant liquor was clear and chromium free, but it had a deep blue color. Two methods of color removal were tried and both were successful.

Activated Carbon:—When activated carbon was added with the iron salts complete color removal resulted at 2,000 p.p.m. dosage. Somewhat less dosage was needed when the carbon was added after chemical treatment and sedimentation, but the disadvantages of a second chemical treatment for the carbon removal precluded its use in this manner. B.O.D. removal amounted to 13 per cent by chemical treatment alone and to 30 per cent when activated carbon was used. Although a rather large dosage of activated carbon was used, the sludge volume did not increase and the sludge dewatered readily on the laboratory sand beds.

Chlorination:—Color removal by chlorination was equally effective and only 100 p.p.m. of chlorine was required. Chlorination had to follow coagulation and sedimentation because the coagulation occurs under conditions of chemical reduction; chlorination involves chemical oxidation.

Plain aeration for B.O.D. removal was tried in the laboratory and found to be of some advantage. It is be-

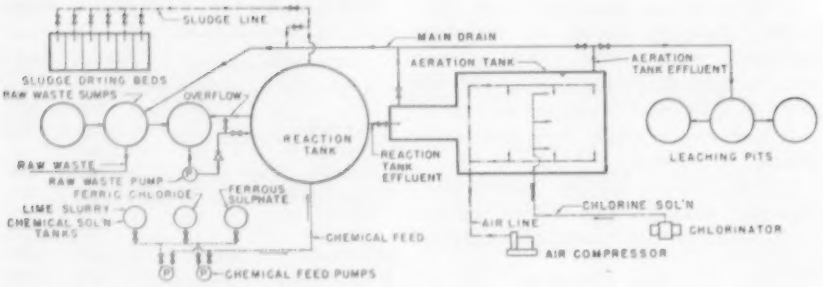

FIGURE 1.—Flow diagram for lithographic waste treatment.

lieved that the removal was accomplished by a physical scrubbing of a portion of the volatile solvents from the liquid.

From the results of the laboratory investigations, it was possible to design the treatment units with confidence and economy. Since B.O.D. removal was not a major consideration, studies were not made of biological treatment methods. Chlorination was recommended for color removal because (1) the effluent would have a lower pH and would thus tend to keep the soil more porous; (2) the residual chlorine would delay biological growth and help reduce soil clogging tendencies; and (3) chlorine was cheaper and easier to handle.

Chemical dosage and effluent characteristics of the laboratory treatment are shown in Table II.

Treatment Facilities

The flow diagram shown in Figure 1 provides for batch treatment with a capacity of 7,500 gal. per batch. This treatment facility was constructed for a large lithograph company.

The raw waste is collected by gravity in three circular underground holding pits. From the holding pits, the waste is pumped to the 12-ft. diameter circular reaction tank having a treatment capacity of 7,500 gal. This tank serves the three-fold purpose of mixing, flocculation, and settling. Mixing and flocculation are accomplished with a two-speed picket fence type mechanism that is provided with sludge squeegees. The reaction tank is provided with multi-level outlets for supernatant selection. From the reaction tank, flow is by gravity to the dual purpose aeration and chlorination basin of 7,500 gal. capacity. This tank is 14½-ft. long, 10-ft. wide, and has a side-water depth of 7 ft. Aeration is accomplished by a positive displacement type rotary blower supplying 360 c.f.m. through perforated pipe diffusers in the bottom of the tank. A chlorinator injects chlorine solution through a perforated pipe in the bottom of the tank. From the aeration and chlorination tank, the flow is by gravity to three 10-ft. diameter leaching wells 10-ft. deep, constructed in the available sand and gravel strata. The leaching area was determined by the usual sewage drain field seepage test.

Chemical feed facilities for ferric chloride, ferrous sulphate, and lime include dissolving tanks and chemical feed pumps. The chemicals are dissolved and pumped to the reaction tank by manual operation of the chemical feed pump.

Sludge from the reaction tank is discharged by gravity to a six-compartment sludge bed having an area of 240 sq. ft. Dried sludge is removed manually and carted away. The sludge bed is of normal open-bed type construction. The filtrate flows

TABLE II.—Chemical Dosage and Effluent Characteristics of Laboratory Treatment for Lithographic Wastes

Chemical Dosage (p.p.m.)	Waste A	Waste B			
	Raw Waste	Raw Waste	Chlorine	Activated Carbon	Chlorine and Aeration[1]
Ferrous sulphate	1,315	456	456	456	456
Ferric chloride	385	291	291	291	291
Lime	750	310	310	310	310
Activated carbon	—	—	—	2,000	—
Chlorine	130	—	100	—	100
Effluent Characteristics					
Solids, total (p.p.m.)	6,125	1,018	—	—	1,000
Volatile solids, total (p.p.m.)	—	470	—	—	—
B.O.D. (p.p.m.)	95	840	720	670	320
Suspended solids (p.p.m.)	3	2	2	2	2
Chromium as Cr^{+6} (p.p.m.)	0	0	0	0	0
pH	4.2	7.0	5.0	8.0	5.0
Color	Clear	Blue	Clear	Clear	Clear

[1] Aeration period, 20 hr.

by gravity to the influent collection wells.

Operating Control and Results

Daily operation consists of pumping a full batch of waste into the reaction tank (on some days two batches are treated). The raw waste is tested for hexavalent chromium using a colorimetric comparison. A chart of tank volume gives the required dosage of ferrous sulphate. Daily requirements over an operating period of 11 months have been sufficiently consistent to allow abandonment of the raw waste test. The ferric chloride requirement is also a constant ratio. Ferrous sulphate and ferric chloride are added by timing the chemical feed pump. Mixing for the required reaction time of one hour is accomplished with the tank mechanism in high speed. This is followed by a 30-min. flocculation period with slow speed stirring. Lime is added to obtain a pH of 8.5; followed by one hour quiescent settling. The amount of lime required also has been essentially constant and a simple test using pH paper has been sufficient. A settleable solids sample is run concurrently with the settling period to indicate sludge volume. The clear supernatant is then withdrawn to the aeration and chlorination tank, and the sludge is discharged to the drying beds. After the aeration period, chlorine is added until the waste is decolorized. Additional chlorine is added as required to provide a chlorine residual of 1 p.p.m. This latter procedure provides for disinfection to assure soil percolation. Average total chlorine dosage is about 100 p.p.m. The effluent hexavalent chromium content as checked from time to time has always been zero.

SEWAGE AND INDUSTRIAL WASTE SAMPLER *

By W. B. Henderson

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In any industrial or domestic waste survey, the problem of obtaining the necessary samples to evaluate properly the strength and volume of the waste being discharged is one that demands immediate attention. There seem to be almost as many solutions to the sampling problem as there are surveys. It would be a boon to those who have the responsibility of compiling the necessary information if it were possible to present a definite procedure and standard equipment for sampling and measuring waste flows.

The great variety of wastes being discharged and the innumerable types of discharge systems being employed to convey the wastes to a receiving stream or body make the selection of equipment and method of sampling a task that varies with each installation.

In a large industrial plant the conditions are not likely to be identical to those of any other plant. However, there are certain factors that are common to the majority of industrial installations and it is for this reason that a discussion of a particular sewage sampler may be of general interest. As a background, a quick glance at some of the methods of sampling and flow measurement usually considered prior to making a waste survey may be worth considering.

Sampler Design Considerations

The first and immediately obvious means in obtaining a sample is the bucket and rope or "grab sample" method. This method has a number of limitations, especially if a sample is desired from some depth of the stream or sewer being measured. An

* Presented at 1954 Annual Meeting, Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.; Nashville, Tenn.; Sept. 20–22, 1954.

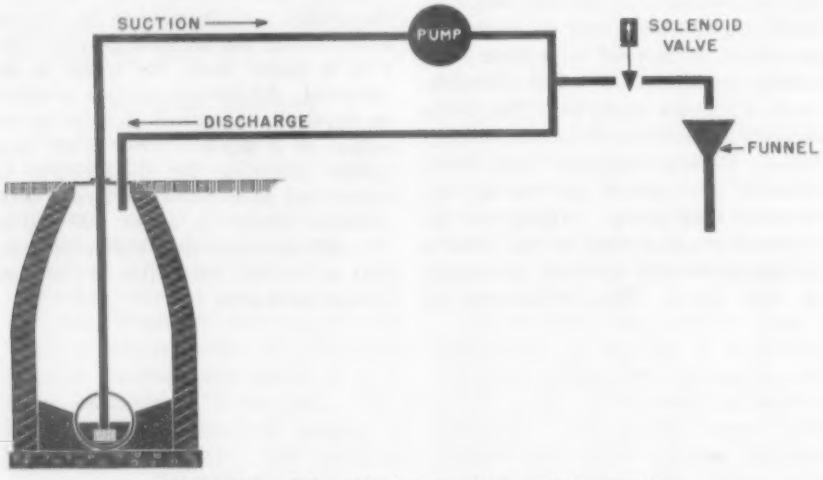

FIGURE 1.—Schematic layout of the waste sampler.

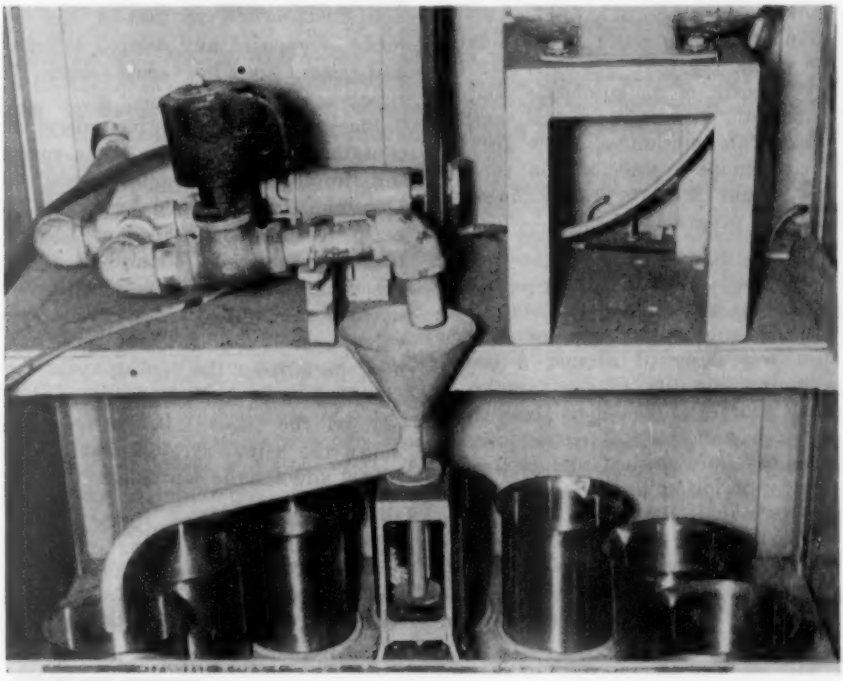

FIGURE 2.—Arrangement of the sampler components inside the trailer. The spring loaded escapement device (not visible) for positioning the funnel is located below the funnel support.

improvement over the bucket, therefore, is one of the sampling devices that can be lowered to a particular depth and used to take a sample at that depth.

For large surveys the automatic sampler is more satisfactory from the standpoint of manpower requirements as well as the completeness of results. In general, automatic samplers can be divided into two categories: (a) those that employ scoops, ladles, or buckets to obtain their samples; and (b) those that employ some form of pumping or vacuum circuit. The scoop, ladle, or bucket type is usually less susceptible to clogging but is generally more difficult to install and therefore less portable.

Naturally, to make maximum use of any sampling device, it is necessary to know the quantity of flow being sampled. This can be done in several ways, including outfall measurements, weirs, flumes, venturi meters, velocity and depth determinations, and others. The type or types selected for a particular sampling program must be tailored to fit the prevailing conditions.

At the plant under study the prevailing conditions were:

1. Ten separate sewer networks discharging individually to the receiving stream.
2. Sewers ranging in size from 4-in. diameter vitrified clay pipe to 9-ft. by 9-ft. concrete box culverts.
3. Manholes ranging in depth from 4 ft. to 16 ft.
4. Flows from 10 to 10,000 g.p.m.
5. Continuous 24-hr. per day, 7 days per week operation.

Although the discharge has been sampled and the waste load evaluated for many years, it was felt that the development of an automatic sampler that would deposit individual samples in separate containers, while keeping a continuous record of the rate of flow, would facilitate greatly the waste disposal program.

The Sampler

Because the size of the sewer system demanded a portable sampler, the unit was designed around a simple pumping circuit. To eliminate as many sources of trouble as possible the pump would operate continuously to keep the lines flushed and lessen the danger of losing prime. This circuit is shown in Figure 1.

To withdraw samples when desired, a connection was made in the discharge line and a solenoid valve added. This valve is controlled by a timer and micro-switch so that it can be made to open at any desired interval and remain open for varied lengths of time.

Placing the samples in individual containers is accomplished by a rotating funnel. This funnel, made of aluminum, is positioned by means of a spring loaded escapement device that is actuated by a solenoid. The timer and micro-switch are arranged so that the solenoids controlling the valve and escapement are synchronized, permitting the timing cycle for sampling to be varied by changing a cam on the timer. In Figure 2 is shown the actual arrangement of the funnel and sample containers.

Flow Recorder

Accuracy required, ease of installation, and durability were the factors considered in determining the type of

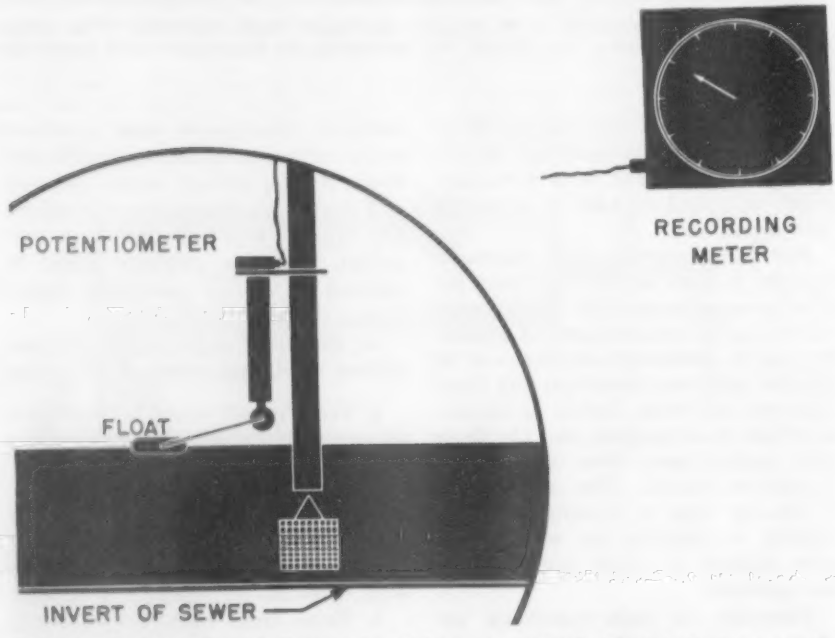

FIGURE 3.—Water level indicator adapted from a gasoline fuel tank indicator and using a recording ammeter calibrated to show depth of flow.

flow recorder to be used. Because the system was so varied and some of the flows quite large, a device that is practical for general use is rather difficult to develop. The use of weirs, while admittedly good from the standpoint of accuracy, was rejected because of the anticipated difficulties to be encountered in their installation. Flumes, venturi meters, and other devices were economically impractical.

The method finally selected employed a recording level indicator and the calibration of the sewers for discharge as related to depth of flow. This calibration made use of a current meter, float and dye solution velocities, as well as computations utilizing the grade of the sewer and the estimated coefficient of roughness.

The water level indicator (Figure 3) is adapted from an airplane fuel tank level indicator, and uses a potentiometer to vary the current through a recording ammeter that has been calibrated to show depth of flow. The potentiometer is bolted to the suction pipe of the sampling device and is connected by means of a transmitting wire to the recording meter mounted at the front of the sampling unit.

The sampler is mounted in a metal housing with a tricycle undercarriage and is equipped with a trailer hitch. If desired, the sampler and level indicator can be used with a weir or flume when the installation of these devices can be carried out with reasonable effort.

At the present time, changes are still being made in the mechanical features of the sampler to improve its efficiency. There is not sufficient operating data to define clearly its capabilities and limitations. It was constructed with only one purpose: to provide the plant with additional facilities for conducting a continuing waste disposal program.

McCALLUM HEADS USPHS WATER POLLUTION CONTROL PROGRAM

Gordon E. McCallum, career sanitary engineer officer of the U. S. Public Health Service, now heads the Water Pollution Control Program, Washington, D. C. The program is charged with the responsibility of carrying out activities of the Public Health Service in connection with interstate pollution problems.

Sanitary Engineer Director McCallum had been chief of the Office of Health Emergency Planning since July 1951. During the past 20 years with the Public Health Service, he has filled engineering assignments in field offices in Atlanta, San Francisco and New Orleans.

BOWER REPLACES KRAUSE AS DIRECTOR OF BDSA

Under the rotation system whereby outstanding business executives serve the Government without compensation for periods of 6 months or longer, Harry F. Bower, official of James B. Clow and Sons, Chicago, was appointed on July 11, 1955 as Director, Water and Sewerage Industry Utilities Division, Business and Defense Services Administration, U. S. Department of Commerce.

He succeeds Charles W. Krause, of the Neptune Meter Co., New York, who has served with BDSA since November 1954.

BIOCHEMICAL OXYGEN DEMAND OF PURE ORGANIC COMPOUNDS

A Report of the Research Committee, FSIWA

By H. Heukelekian and M. C. Rand

A knowledge of the B.O.D. of pure organic chemicals is of importance from the standpoint of treatment of industrial wastes. Chemicals used in the production of a certain product are known. The amount of these chemicals lost to the waste water can be estimated. If the B.O.D. of the particular chemical is known, it is possible to estimate the B.O.D. load contributed by the chemical.

A similar approach can be used when the loss of the quantity of a chemical product is known. It is thus possible to determine the B.O.D. discharged by a given process. If the B.O.D. of waste discharged by a given process happens to be too high, then measures can be taken for segregation.

During the past five years, a number of papers have been published containing some valuable information regarding the B.O.D. of pure compounds. The compilation of these data seemed desirable in order to make the information readily available. In addition, the authors have obtained some unpublished data from a number of individuals and organizations. This is being presented as a report of the Research Committee of the Federation of Sewage and Industrial Wastes Associations as a service to the profession.

The compilation is probably not complete, and will probably be out of date very shortly. There are probably data of similar nature in the files of many individuals and organizations. As such data are made available to the Chairman of the Research Committee, they can be included in subsequent publications to bring the data up to date.

The list of chemical compounds has been assembled into fourteen broad groups on the basis of certain chemical similarities. Within these broad groups they have been listed in the order of increasing complexity rather than alphabetically.

There may be a certain amount of criticism to the breakdown into groups and listing within the groups used. There is, however, no single classification of these organic compounds that will be free from such criticism. The alternative would be an alphabetical arrangement, which at the same time would make it easier to locate a specific compound. Such a system of listing, however, would bring completely unrelated compounds together.

A minimum amount of essential information is included in the tables. The concentration at which the B.O.D. of a given compound is determined is important in many instances. Unfortunately, often this information is not reported in the original papers.

The B.O.D. values are expressed as grams per gram of chemical tested. This is a convenient and basic method of expression. The values would be the same on the basis of pounds or any other weight measure desired.

Most of the data reported are for a 5-day incubation period. There are a few 10-day and ultimate values. All the data are for 20° C.

The standard dilution method is the common method employed, using sewage as seed. There are a number of results using manometric methods and specially adapted seeds and cultures.

Additional information contained

TABLE I.—B.O.D. of Organic Acids and Their Salts

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Formic acid	—	0.19	5	St. dil.	Sewage	25
Formic acid	—	0.27	5	St. dil.	Sewage	5
Formic acid	—	0.152	5	St. dil.	Sewage	22
Formic acid	—	0.02	5	St. dil.	Sewage	27
Sodium formate	—	0.096	5	St. dil.	Sewage	21
Sodium formate	—	0.04	5	St. dil.	Sewage	25
Calcium formate	—	0.20	10	St. dil.	Sewage	2
Acetic acid	—	0.88	5	St. dil.	Sewage	25
Acetic acid	—	0.85	5	St. dil.	Sewage	5
Acetic acid	—	0.77	5	St. dil.	Sewage	6
Acetic acid	—	0.53	5	St. dil.	Sewage	20
Acetic acid	—	0.586	5	St. dil.	Sewage	22
Acetic acid	—	0.45	5	St. dil.	—	24
Acetic acid	—	0.34	5	St. dil.	Sewage	27
Acetic acid	—	0.52	5	St. dil.	Sewage	28
Acetic acid	—	0.62	5	St. dil.	Sewage	29
Sodium acetate	2.5–10	0.27	5	St. dil.	Sewage	5
Sodium acetate	—	0.67	5	St. dil.	Sewage	6
Sodium acetate	2.5–20	0.33	5	St. dil.	Sewage	19
Sodium acetate	865	0.39	5	Sierp	Sewage[1]	19
Sodium acetate	250	0.38	5	Warburg	Sewage[1]	19
Sodium acetate	—	0.11, 0.17 0.35, 0.43	5	St. dil.	sp. cult.	21
Sodium acetate	—	0.32	5	St. dil.	Sewage	27
Calcium acetate	—	0.43	5	St. dil.	Sewage	25
Dichloracetic acid	—	0	5	St. dil.	Sewage	20
Propionic acid	2	0.36	5	St. dil.	sp. cult.	23
Propionic acid	2	0.69	10	St. dil.	sp. cult.	23
Propionic acid	—	0.837	5	St. dil.	Sewage	22
Sodium propionate	—	0.52	5	St. dil.	Sewage	13
Sodium propionate	—	0.36	5	St. dil.	sp. cult.	21
Sodium propionate	1,000	0.61	5	Manom.	Sewage	13
Butyric acid	2	0.34	5	St. dil.	sp. cult.	23
Butyric acid	2	0.74	10	St. dil.	sp. cult.	23
Butyric acid	—	0.90	5	St. dil.	—	24
Butyric acid	—	0.89	5	St. dil.	Sewage	22
Sodium butyrate	—	0.41	5	St. dil.	sp. cult.	21
Sodium isobutyrate	—	0.43	5	St. dil.	sp. cult.	21
Valeric acid	—	1.059	5	St. dil.	Sewage	22
Sodium valerate	—	0.48	5	St. dil.	sp. cult.	21
Sodium isovalerate	—	0.57	5	St. dil.	sp. cult.	21
Sodium caproate	—	0.69	5	St. dil.	sp. cult.	21
Glucono delta lactone	—	0.52	5	St. dil.	Sewage	27
Sodium heptylate	—	0.33, 0.82, 0.44	5	St. dil.	sp. cult.	21
Sodium caprylate	—	0.76	5	St. dil.	sp. cult.	21

[1] 10 per cent.

TABLE I.—(Continued)

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Nonylic acid	—	0.59	5	St. dil.	Sewage	22
Palmitic acid	—	1.07	5	St. dil.	Sewage	22
Sodium palmitate	—	1.02, 0.45, 0.40	5	St. dil.	sp. cult.	21
Stearic acid	—	0.786	5	St. dil.	Sewage	22
Sodium stearate	—	0.45, 0.51	5	St. dil.	Sewage	21
Sodium stearate	2.5–20	1.20	5	St. dil.	Sewage	19
Sodium stearate	865	1.40	5	Sierp	Sewage[1]	19
Sodium stearate	250	1.72	5	Warburg	Sewage[1]	19
Glycolic acid	—	0.175	5	St. dil.	Sewage	22
Oxalic acid	—	0.14	5	St. dil.	Sewage	30
Oxalic acid	—	0.10	5	St. dil.	Sewage	22
Sodium oxalate	2.5–20	0.08	5	St. dil.	Sewage	19
Sodium oxalate	865	0.16	5	Sierp	Sewage[1]	19
Sodium oxalate	250	0.085	5	Warburg	Sewage[1]	19
Lactic acid	—	0.63	5	Warburg	Sewage	22
Lactic acid	2	0.64	5	St. dil.	sp. cult.	23
Lactic acid	2	0.88	10	St. dil.	sp. cult.	23
Succinic acid	—	0.64	5	Warburg	Sewage	22
Succinic acid	2	0.21	5	St. dil.	sp. cult.	23
Succinic acid	2	0.31	10	St. dil.	sp. cult.	23
Fumaric acid	—	0.60, 0.70	5	Warburg	Sewage	4
Fumaric acid	3.75–7.5	0.57	5	Warburg	Sewage	5
Malic acid	—	0.57	5	Warburg	Sewage	5
Malic acid	2.5–10	0.34	5	Warburg	Sewage	5
Maleic acid	—	0.38	5	Warburg	Sewage	5
Maleic anhydride	3.75–7.5	0.60	5	Warburg	Sewage	5
Maleic anhydride	—	0.40	5	Warburg	Sewage	4
Tartaric acid	—	0.30	5	Warburg	Sewage	22
Mucic acid	—	0.245	5	Warburg	Sewage	22
Citric acid	—	0.40	5	Warburg	Sewage	22
Sodium citrate	2.5–20	0.32	5	Warburg	Sewage	19
Sodium citrate	865	0.39	5	Sierp	Sewage[1]	19
Sodium citrate	250	0.39	5	Warburg	Sewage[1]	19
Undecylenic acid	—	0.537	5	St. dil.	Sewage	22
Sodium oleate	—	1.29	5	St. dil.	Sewage	13
Sodium oleate	—	0.47, 0.56	5	St. dil.	sp. cult.	21
Sodium oleate	1,000	1.43	5	Manom.	Sewage	13
Benzoic acid	—	1.40	10	St. dil.	Sewage	2
Benzoic acid	—	1.34	5	St. dil.	Sewage	20
Benzoic acid	—	1.40	5	St. dil.	Sewage	22
Sodium benzoate	—	1.13	5	St. dil.	Sewage	19
Sodium benzoate	440	1.36	5	St. dil.	Sewage	19
Benzoyl benzoic acid	—	.001	5	St. dil.	Sewage	4

TABLE I.—(Continued)

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Salicylic acid, ortho	—	0.95	5	St. dil.	Sewage	22
Mandelic acid	—	0.31	5	St. dil.	Sewage	22
Phthalic acid	—	0.85	5	St. dil.	Sewage	5
Phthalic acid	—	0.89	5	St. dil.	Sewage	5
Phthalic acid	—	1.44	5	St. dil.	Sewage	22
Phthalic anhydride	—	1.20	5	St. dil.	Sewage	5
Phthalic anhydride	1–4	1.26	5	St. dil.	Sewage	5
Phthalic anhydride	—	0.72	5	St. dil.	Sewage	25
Anthranilic acid	—	1.32	5	St. dil.	Sewage	20
Sulfanilic acid	—	1.11	5	St. dil.	Sewage	22
Toluene sulfonic acid	—	0	5	St. dil.	Sewage	20
Anthraquinone sulfonic acid	—	0	5	St. dil.	Sewage	20
Gallic acid	—	0.08	5	St. dil.	Sewage	22
Tannic acid	—	0.31	5	St. dil.	Sewage	22
Tannic acid	—	0.46	5	St. dil.	—	24
Methacrylic acid	—	0.89	5	St. dil.	Sewage	25
Methyl methacrylic acid	—	0.14	5	St. dil.	Sewage	25
Ethylene diamine tetracetic acid	—	0.01	5	St. dil.	Sewage	29

in the original can be readily obtained from the corresponding references.

The limitations and inadequacies of this tabulation are apparent from a perusal of the tables. There are some glaring inconsistencies and variations in the values for a given compound reported by the same or different authors employing the same method. There are also a great number of good agreements among such results. For a number of compounds, the replications are meager. The use of sewage seed and the use of the 5-day incubation period does not necessarily represent the potential B.O.D. in most of these compounds.

With all these limitations, it is felt that the compilation gives a picture of the present status of this problem. It shows where adequate information is available and where additional work should be done to develop more reliable data.

(See following pages for additional Tables and References)

TABLE II.—B.O.D. of Alcohols

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Methyl alcohol	—	0.80	5	St. dil.	Sewage	1
Methyl alcohol	1–5	1.12	5	St. dil.	Sewage	5
Methyl alcohol	—	0.90	5	St. dil.	Sewage	6
Methyl alcohol	1–10	0.76	5	St. dil.	Sewage	16
Methyl alcohol	2.5–7.5	0.77	5	St. dil.	Sewage	19
Methyl alcohol	—	0.80	5	St. dil.	Sewage	20
Methyl alcohol	—	0.90	5	St. dil.	Sewage	18
Methyl alcohol	—	0.93	5	St. dil.	Sewage	18
Methyl alcohol	—	0.90	5	St. dil.	Sewage	22
Methyl alcohol	500–1,500	0.13	5	Sierp	Sewage[1]	19
Methyl alcohol	50–250	0.80	5	Warburg	Sewage[1]	19
Methyl alcohol	1,000	0.60	5	Warburg	Sewage[1]	18
Methyl alcohol	—	0.77	5	St. dil.	—	24
Methyl alcohol	—	0.82	5	St. dil.	—	25
Ethyl alcohol	—	1.67	5	St. dil.	Sewage	5
Ethyl alcohol	—	1.44	5	St. dil.	Sewage	6
Ethyl alcohol	1–10	1.07	5	St. dil.	Sewage	16
Ethyl alcohol	—	1.25	5	St. dil.	Sewage	18
Ethyl alcohol	2.5–7.5	1.14	5	St. dil.	Sewage	19
Ethyl alcohol	—	1.40	5	St. dil.	Sewage	20
Ethyl alcohol	—	1.26	5	St. dil.	Sewage	20
Ethyl alcohol	—	1.29	5	St. dil.	Sewage	22
Ethyl alcohol	1,000	1.50	5	Warburg	Sewage[1]	18
Ethyl alcohol	500–1,500	1.37	5	Sierp	Sewage[1]	19
Ethyl alcohol	50–250	1.52	5	Warburg	Sewage[1]	19
Ethyl alcohol	2	1.03	5	St. dil.	sp. cult.	23
Ethyl alcohol	2	1.56	10	St. dil.	sp. cult.	23
Ethyl alcohol	—	1.00	5	St. dil.	Sewage	25
Ethyl alcohol	—	0.93	5	St. dil.	Sewage	1
n-Propyl alcohol	—	0.47	5	St. dil.	Sewage	25
n-Propyl alcohol	—	1.5	5	St. dil.	Sewage	6
iso-Propyl alcohol	—	1.29, 1.59	5	St. dil.	Sewage	18
iso-Propyl alcohol	—	1.29	5	St. dil.	Sewage	20
iso-Propyl alcohol	—	1.42	5	St. dil.	Sewage	22
iso-Propyl alcohol	1,000	0.075	5	Warburg	Sewage[1]	20
Allyl alcohol	—	1.60	10	St. dil.	Sewage	2
Glycerol	—	0.65	5	St. dil.	Sewage	19
Glycerol	—	0.80	5	St. dil.	Sewage	20
Glycerol	—	0.617	5	St. dil.	Sewage	22
Glycerol	150–500	0.78	5	Sierp	Sewage[1]	19
Glycerol	50–250	0.83	5	Warburg	Sewage[1]	19
Glycerol	2	0.81	5	St. dil.	sp. cult.	23
Glycerol	2	0.98	10	St. dil.	sp. cult.	23
Glycerol	—	0.64	5	St. dil.	Sewage	30

[1] 10 per cent.

TABLE II (Continued)

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
n-Butyl alcohol	—	1.45	5	St. dil.	Sewage	6
n-Butyl alcohol	1–5	1.10	5	St. dil.	Sewage	16
n-Butyl alcohol	—	1.5, 1.65	5	St. dil.	Sewage	18
n-Butyl alcohol	1–10	1.45	5	St. dil.	Sewage	16
n-Butyl alcohol	2.5–7.5	1.30	5	St. dil.	Sewage	19
n-Butyl alcohol	—	1.50	5	St. dil.	Sewage[1]	20
n-Butyl alcohol	1,000	1.79	5	Warburg	Sewage[1]	18
n-Butyl alcohol	1–5	1.92	5	St. dil.	Sewage	26
n-Butyl alcohol	500–1,500	1.67	5	Sierp	Sewage[1]	19
n-Butyl alcohol	50–250	2.04	5	Warburg	Sewage[1]	19
iso-Butyl alcohol	—	1.66	5	St. dil.	Sewage	22
iso-Butyl alcohol	—	0.07	5	St. dil.	Sewage	25
n-Amyl alcohol	—	1.50	5	St. dil.	Sewage	4
n-Amyl alcohol	—	1.61	5	St. dil.	Sewage	6
iso-Amyl alcohol	—	1.50	5	St. dil.	Sewage	6
iso-Amyl alcohol	—	1.62	5	St. dil.	Sewage	22
Amyl alcohol	—	1.23	5	St. dil.	Sewage	13
Amyl alcohol	10–20	1.10	5	St. dil.	Sewage	16
Amyl alcohol	—	1.26	5	St. dil.	Sewage	22
Amyl alcohol	1,000	1.54	5	Sierp	Sewage[1]	13
Amyl alcohol	1,000	1.59	5	Warburg	Sewage[1]	13
Amyl alcohol	500–1,500	1.59	6	Sierp	Sewage[1]	19
Allyl alcohol	—	0.20	5	St. dil.	Sewage	1
Cyclohexanol	—	0.08	5	St. dil.	Sewage	22
Mannitol	—	0.68	5	St. dil.	Sewage	22
Octyl alcohol	—	1.09	5	St. dil.	Sewage	22
Ethylene glycol	—	0.16	5	St. dil.	Sewage	1
Ethylene glycol	—	1.10	10	St. dil.	Sewage	2
Ethylene glycol	12	0.68	5	St. dil.	Sewage	15
Ethylene glycol	12	0.93	10	St. dil.	Sewage	15
Ethylene glycol	—	0.49	5	St. dil.	Sewage	22
Ethylene chlorohydrin	—	0.50	10	St. dil.	Sewage	2
Diethylene glycol	—	nil	10	St. dil.	Sewage	2
Diethylene glycol	—	0.02	5	St. dil.	Sewage	1
Diethylene glycol	—	0.06	5	St. dil.	Sewage	30
Triethylene glycol	—	0.50	10	St. dil.	Sewage	2
Tetraethylene glycol	—	0.50	10	St. dil.	Sewage	2
Polyethylene glycol	—	0.08, 0.30	10	St. dil.	Swcage	2
Ethylene glycol monoethyl ether	—	1.1	10	St. dil.	Sewage	2
1,5 Pentanediol	—	2.0	10	St. dil.	Sewage	2
Methyl phenyl carbinol	—	1.0	10	St. dil.	Sewage	2
Methyl phenyl carbinol redistilled	—	2.1	10	St. dil.	Sewage	2
Benzyl alcohol	—	1.55	5	St. dil.	Sewage	22

TABLE III.—B.O.D. of Aldehydes, Ketones and Quinones

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Formaldehyde	—	1.06	5	St. dil.	Sewage	6
Formaldehyde	—	0.64	5	St. dil.	Sewage	22
Formaldehyde	2.5–10	0.33	5	St. dil.	Sewage	16
Formaldehyde	1.7–20	0.45	5	St. dil.	Sewage	9
Formaldehyde	260	1.10	5	Manom.	Sewage[1]	17
Formaldehyde	260	0.57	5	Manom.	Sewage[2]	17
Formaldehyde	440	0	5	Sierp	Sewage[3]	19
Formaldehyde	130	1.00	7	Warburg	Sewage[1]	20
Formaldehyde	260	1.10	5	Warburg[4]	Sewage[5]	20
Formalin, 35 per cent	—	0.37	5	St. dil.	Sewage	27
Acetaldehyde	—	1.27	5	St. dil.	Sewage	6
Butyraldehyde	—	1.06	5	St. dil.	Sewage	1
n-Butyraldehyde	—	1.62	5	St. dil.	Sewage	6
iso-Butyraldehyde	—	1.62	5	St. dil.	Sewage	6
Acetaldol	—	0.90	10	St. dil.	Sewage	2
Crotonaldehyde	—	1.30	10	St. dil.	Sewage	2
Furfural	1.7–20	0.77	5	St. dil.	Sewage	19
Furfural	440	0.28	5	Sierp	Sewage[3]	19
Benzaldehyde	—	1.50	10	St. dil.	Sewage	2
Acetone	—	1.20	10	St. dil.	Sewage	2
Acetone	—	1.39	5	St. dil.	Sewage	6
Acetone	10	0.31	5	St. dil.	Sewage	16
Acetone	1.7–20	0.05–0.72	5	St. dil.	Sewage	19
Acetone	12	1.43	5	St. dil.	Sewage	15
Acetone	12	1.63	10	St. dil.	Sewage	15
Acetone	—	0.544	5	St. dil.	Sewage	22
Acetone	440	0	5	Sierp	Sewage[3]	19
Acetone	—	0.69	5	St. dil.	Sewage	25
Methyl ethyl ketone	—	2.14	5	St. dil.	Sewage	6
Diethyl ketone	—	1.00	10	St. dil.	Sewage	2
Methyl isobutyl ketone	—	0.12	5	St. dil.	Sewage	1
Methyl isobutyl ketone	—	0.6	10	St. dil.	Sewage	2
Methyl isobutyl ketone	—	2.14	5	St. dil.	Sewage	6
Methyl n-amyl ketone	—	0.50	10	St. dil.	Sewage	2
Methyl phenyl ketone	—	1.40	10	St. dil.	Sewage	2
Methyl phenyl ketone	—	0.518	5	St. dil.	Sewage	2
1:4 Naphtho quinone	—	0.81	5	St. dil.	Sewage	5

[1] 50 per cent.
[2] 5 per cent.
[3] 10 per cent.
[4] Adapted.
[5] 25 to 50 per cent.

TABLE IV.—B.O.D. of Amines and Amides

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Ethanolamine	—	0.78	5	St. dil.	Sewage	20
Monoethanolamine	2.5	0.80, 1.10	5	St. dil.	Sewage	1
Diethanolamine	2.5	0.10	5	St. dil.	Sewage	1
Triethanolamine	—	nil	10	St. dil.	Sewage	2
Triethanolamine	—	0.01	5	St. dil.	Sewage	27
Triethanolamine	—	0	5	St. dil.	Sewage	1
Aniline	—	1.49	5	St. dil.	Sewage	22
Aniline	—	2.26	5	St. dil.	Sewage	5
Aniline	1.5–3	1.47	5	St. dil.	Sewage	5
Aniline	—	1.50	5	St. dil.	Sewage	27
Diethylaniline	—	0	5	St. dil.	Sewage	20
Melamine	—	0, 0.006	5	St. dil.	Sewage	4
Butylamine hydrochloride	—	1.25	5	St. dil.	Sewage	4
Hexamethylene tetramine	—	0.015, 0.026	5	St. dil.	Sewage	4
p-Toluidine	2.5	1.63	5	St. dil.	Sewage	5
p-Toluidine	—	1.44	5	St. dil.	Sewage	22
o-Toluidine	1.25–2.5	1.43	5	St. dil.	Sewage	5
o-Toluidine	—	0.24	5	St. dil.	Sewage	22
Morpholine	—	nil	10	St. dil.	Sewage	2
Morpholine	—	.02	5	St. dil.	Sewage	1
Diamino pyridine	—	0	5	St. dil.	Sewage	22
Monoethyl aniline	—	0.048	5	St. dil.	Sewage	22
Dimethyl aniline	—	0.25	5	St. dil.	Sewage	22
Diethyl aniline	—	0	5	St. dil.	Sewage	22
Xylidine	—	0	5	St. dil.	Sewage	22
Naphthylamine	—	0.89	5	St. dil.	Sewage	22
Acetanilide	—	1.20	10	St. dil.	Sewage	2
n-Acetyl ethanolamine	—	1.10	10	St. dil.	Sewage	2
n-Acetyl morpholine	—	nil	10	St. dil.	Sewage	2
Acrylonitrile	—	0.70	10	St. dil.	Sewage	2
Formamide	—	0	5	St. dil.	Sewage	25

TABLE V.—B.O.D. of Carbohydrates

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Glucose	—	0.53	5	St. dil.	Sewage	27
Glucose	—	0.62	5	St. dil.	Sewage	6
Glucose	—	0.63	5	St. dil.	Sewage	7
Glucose	—	0.53	5	St. dil.	sp. cult.	8
Glucose	—	0.64	5	St. dil.	Sewage	13
Glucose	2.5–20	0.64	5	St. dil.	Sewage	13
Glucose	—	.50	5	St. dil.	Sewage	22
Glucose	1,000	0.74	5	Manom.	Sewage	13
Glucose	865	0.77	5	Sierp	Sewage	19
Glucose	250	0.72	5	Warburg	Sewage	19
Glucose	2	0.78	5	St. dil.	sp. cult.	23
Glucose	2	1.01	10	St. dil.	sp. cult.	23
Glucose	5	0.74	5	St. dil.	Sewage	26
Sucrose	1.25–7	0.688	5	St. dil.	Sewage	5
Sucrose	2.5–20	0.70	5	St. dil.	Sewage	19
Sucrose	865	0.67	5	Sierp	Sewage	19
Sucrose	250	0.70	5	Warburg	Sewage	19
Sucrose	—	0.49	5	St. dil.	Sewage	24
Sucrose	5	0.76	5	St. dil.	Sewage	26
Lactose	—	0.45	5	St. dil.	—	24
Lactose	2.5–20	0.52	5	St. dil.	Sewage	19
Lactose	—	0.55	5	St. dil.	Sewage	22
Lactose	865	0.72	5	Sierp	Sewage	19
Lactose	250	0.65	5	Warburg	Sewage	19
Starch	2	0.22	5	St. dil.	sp. cult.	23
Starch	2	0.59	10	St. dil.	sp. cult.	23
Starch	2.5–20	0.51	5	St. dil.	Sewage	19
Starch	865	0.71	5	Sierp	Sewage	19
Starch	250	0.67	5	Warburg	Sewage	19
Starch	1,000	0.69	5	Manom.	Sewage	13
Starch	—	0.51	5	St. dil.	Sewage	13
Starch	—	0.63	5	St. dil.	Sewage	15
Starch	—	0.68	5	St. dil.	Sewage	22
Starch	20	0.39	5	St. dil.	Sewage	15
Starch	20	0.55	10	St. dil.	Sewage	15
Starch modified	20	0.15	5	St. dil.	Sewage	15
Starch modified	20	0.43	10	St. dil.	Sewage	15
Starch (corn)	—	1.25	5	St. dil.	Sewage	25
Starch (corn)	—	0.60	5	St. dil.	Sewage	26
Starch (corn)	—	0.50	5	St. dil.	Sewage	30
Starch (wheat)	—	0.55	5	St. dil.	Sewage	30
Dextrin	—	.40	5	St. dil.	Sewage	22
Dextrin	—	.50	5	St. dil.	Sewage	27

TABLE V.—(Continued)

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Cellulose	2	0.08	5	St. dil.	sp. cult.	23
Cellulose	2	0.21	10	St. dil.	sp. cult.	23
Cellulose, alpha	10,000	0.15	5	Sierp	Sewage	15
Cellulose, alpha	10,000	0.40	10	Sierp	Sewage	15
Cellulose, alpha	10,000	0.89	20	Sierp	Sewage	15
Cellulose, alpha	10,000	1.1	80	Sierp	Sewage	15
Cellulose, alpha	10,000	0.70	5	Sierp	Adapted	15
Cellulose, alpha	10,000	1.03	10	Sierp	Adapted	15
Cellulose, alpha	10,000	1.1	20	Sierp	Adapted	15
Methylcellulose	165	0.008	5	St. dil.	Sewage	15
Carboxymethylcellulose	—	0.3	5	St. dil.	Sewage	30
Lignin	2	0	5	St. dil.	sp. cult.	23
Lignin	2	0	5	St. dil.	sp. cult.	23

TABLE VI.—B.O.D. of Dyes

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Methyl orange	—	0	5	St. dil.	Sewage	22
Aniline yellow	—	0	5	St. dil.	Sewage	22
Tropeolin 0 0	—	0	5	St. dil.	Sewage	22
Congo red	—	0	5	St. dil.	Sewage	22
Malachite green	—	0	5	St. dil.	Sewage	22
Methyl violet	—	0	5	St. dil.	Sewage	22
Phloxin	—	0	5	St. dil.	Sewage	22
Bromthymol blue	—	0	5	St. dil.	Sewage	22
Phenol red	—	0	5	St. dil.	Sewage	22

TABLE VII.—B.O.D. of Esters

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Ethyl formate	—	0.5	10	St. dil.	Sewage	2
Ethyl acetate	—	1.13	5	St. dil.	Sewage	6
Ethyl acetate	—	0.29	5	St. dil.	Sewage	22
Ethyl acetate	1,000	1.14	4	Sierp	Sewage	12
Ethyl acetate	1,000	0.76	4	Sierp	Sewage	19
Ethyl acetate	1,000	0.81	4	Sierp	Sewage	19
Ethyl acetate	1,000	0.80	4	Sierp	Sewage	19
Ethyl acetate	1,000	0.83	4	Sierp	Adapted	19
Ethyl acetate	1,000	1.14	4	Sierp	Sewage[1]	19
Ethyl acetate	1.7–20	0.57	5	St. dil.	Sewage	19
Ethyl acetate	440	0.92	5	Sierp	Sewage[2]	19
Ethyl acetate	—	0.66	5	St. dil.	Sewage	1
Ethyl acetate	—	0.86	5	St. dil.	Sewage	25
Butyl acetate	—	0.52	5	St. dil.	Sewage	1
Butyl acetate	—	0.15	5	St. dil.	Sewage	22
Amyl acetate	1.7–20	0.31	5	St. dil.	Sewage	19
Amyl acetate	440	0.88	5	Sierp	Sewage[2]	19
Dibutyl phthalate	—	0.43	5	St. dil.	Sewage	25
Isopropyl acetate	—	0.26	5	St. dil.	Sewage	1

[1] Buffered.
[2] 10 per cent.

TABLE VIII.—B.O.D. of Ethers and Polymers

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Ethyl ether	—	0.03	5	St. dil.	Sewage	16
Diethyl ether	—	nil	10	St. dil.	Sewage	2
Ethylene glycol monomethyl ether (methyl cellosolve)	—	1.10	10	St. dil.	Sewage	2
Ethylene glycol diethyl ether	—	0.10	10	St. dil.	Sewage	2
Ethylene glycol monoethyl ether	5–10	1.58	5	St. dil.	Sewage	26
Diethylene glycol monomethyl ether acetate (methyl carbitol acetate)	—	1.10	10	St. dil.	Sewage	2
Diethylene glycol diethyl ether	—	0.10	10	St. dil.	Sewage	2
Polyethylene glycol	—	0.08, 0.03	10	St. dil.	Sewage	2
Polyethylene glycol diacetate	—	0.20	10	St. dil.	Sewage	2
Dioxane	—	nil	10	St. dil.	Sewage	2
Iso-amyl ether	—	0	5	St. dil.	Sewage	22

TABLE IX.—B.O.D. of Heterocyclic Compounds

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Pyridine	—	1.47	5	St. dil.	Sewage	3
Pyridine	1.7–20	0	5	St. dil.	Sewage	19
Pyridine	440	0	5	Sierp	Sewage[1]	19
Pyridine	—	0	5	St. dil.	Sewage	20
Pyridine	—	1.15	5	St. dil.	Sewage	22
Quinoline	—	1.71	5	St. dil.	Sewage	22

[1] 10 per cent.

TABLE X.—B.O.D. of Hydrocarbons

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Gasoline	2.5–5	0.078	5	St. dil.	Sewage	16
Kerosene	1–15	0.53	5	St. dil.	Sewage	16
Benzene	—	1.20	10	St. dil.	Sewage	2
Benzene	—	0	5	St. dil.	Sewage	22
Toluene	—	0	5	St. dil.	Sewage	22
Xylene	—	0	5	St. dil.	Sewage	22
Naphthalene	—	0	5	St. dil.	Sewage	22
α-Methylnaphthalene		0	5	St. dil.	Sewage	22
Tetrahydronaphthalene (tetralin)		0	5	St. dil.	Sewage	22
Halogenated Hydrocarbons						
Ethylene dichloride	—	0.05	10	St. dil.	Sewage	22
Ethylene dichloride	—	0.002	5	St. dil.	Sewage	16
Chloroform	—	0.008	5	St. dil.	Sewage	16
Chloroform	—	0	5	St. dil.	Sewage	2
Carbon tetrachloride	—	0	5	St. dil.	Sewage	22
Monochlorobenzene	—	0.03	5	St. dil.	Sewage	29
Nitrated Hydrocarbons						
Nitrobenzene	1.7–20	0	5	St. dil.	Sewage	19
Nitrobenzene	440	0	5	Sierp	Sewage[1]	19

[1] 10 per cent.

TABLE XI.—B.O.D. of Phenolic Compounds

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Phenol	—	2.1	10	St. dil.	Sewage	2
Phenol	—	1.71	5	St. dil.	Sewage	5
Phenol	1.25–2.5	1.81	5	St. dil.	Sewage	5
Phenol	—	1.78	5	St. dil.	Sewage	22
Phenol	—	1.40	5	St. dil.	Sewage	24
Phenol	1,000	2.0	5	Manom.	Adapted	12
Phenol	1,000	0.05	5	Manom.	Sewage	12
Phenol	500	0.54	4	Sierp	Sewage[1]	19
Phenol	500	1.84	4	Sierp	Adapted[1]	19
Phenol	1,000	1.88	5	Sierp	Adapted[1]	19
ortho Cresol	—	1.64	5	St. dil.	Sewage	22
meta Cresol	—	1.70	5	St. dil.	Sewage	22
p-Cresol	1.7–20	1.40	5	St. dil.	Sewage	19
p-Cresol	440	1.48	5	Sierp	Sewage[2]	19
Xylenol 1:3:5	—	0.82	5	St. dil.	Sewage	22
Xylenol 1:3:4	—	1.50	5	St. dil.	Sewage	22
Pyrocatechol	—	0.69	5	St. dil.	Sewage	22
Resorcinol	—	1.15	5	St. dil.	Sewage	22
Hydroquinone	—	0.48	5	St. dil.	Sewage	22
Pyrogallol	—	0.016	5	St. dil.	Sewage	22
Phloroglucinol	—	0.47	5	St. dil.	Sewage	22
Guiacol	—	1.40	5	St. dil.	Sewage	22
Naphthol, alpha	—	1.69	5	St. dil.	Sewage	22
Naphthol, alpha	—	1.75	5	St. dil.	Sewage	22
Naphthol, beta	0.75–3	1.79	5	St. dil.	Sewage	5
Oxyquinoline	—	0	5	St. dil.	Sewage	22

[1] 50 per cent.
[2] 10 per cent.

TABLE XII.—B.O.D. of Proteins, Amino Acids, and Their Degradation Products

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Casein	—	0.25	5	St. dil.	Sewage	27
Casein	—	0.77	5	St. dil.	Sewage	13
Casein	1,000	0.95	5	Manom.	Sewage	13
Casein	2.5–20	0.77	5	St. dil.	Sewage	13
Casein	865	1.01	5	Sierp	Sewage	19
Casein	250	0.89	5	Warburg	Sewage	19
Casein	—	0.57	5	St. dil.	Sewage	22
Casein	—	1.17	5	St. dil.	Sewage	25
Gelatin	—	0.88	5	St. dil.	Sewage	25
Gelatin	2.5–20	0.55	5	St. dil.	Sewage	19
Gelatin	865	0.66	5	Sierp	Sewage	19
Gelatin	250	0.69	5	Warburg	Sewage	19
Gelatin	10	0.92	5	St. dil.	Sewage	26
Peptone	—	0.15	5	St. dil.	Sewage	22
Peptone	5	0.88	5	St. dil.	Sewage	26
Uric acid	—	0.30	5	St. dil.	Sewage	22
Indol	—	2.07	5	St. dil.	Sewage	2
Skatol	—	1.51	5	St. dil.	Sewage	2
Glycine	—	0.55	5	St. dil.	Sewage	22
Glycine	5	0.52	5	St. dil.	Sewage	26
Alanine	—	0.94	5	St. dil.	Sewage	22
Aspartic acid	—	0.58	5	St. dil.	Sewage	22
Glutamic acid	—	0.64	5	St. dil.	Sewage	7
Glutamic acid	—	0.45	ult.	St. dil.	Sewage[1]	9
Glutamic acid	—	0.42	ult.	St. dil.	Sewage[1]	9

[1] Frozen.

TABLE XIII.—B.O.D. of Soaps and Detergents (Commercial)

Compound	Conc. (p.p.m.)	B.O.D. (g./g.)	Incub. Time (days)	Method	Seed	Ref.
Ivory Snow	—	1.41	5	St. dil.	Sewage	14
Lux Flakes	—	1.47	5	St. dil.	Seawge	14
Super Suds	—	0.97	5	St. dil.	Sewage	14
Dreft	—	0.49	5	St. dil.	Sewage	14
Nacconol N.R. (Swerl)	—	0	5	St. dil.	Sewage	14
Nacconol N.R.	—	.02	5	St. dil.	Sewage	30
Tween 80	—	0.35	5	St. dil.	Sewage	15
Sodium alginate	4	0.36	5	St. dil.	Sewage	15

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CERAMIC WASTE TREATMENT *

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The Locke Plant in Baltimore, has manufactured insulators since 1920 and has been a part of the General Electric Company since 1934. The wastes have always been discharged to the Patapsco River adjacent to the plant. Wastes from a ceramic manufacturing plant such as Locke are a mixture of clays which have an equivalent spherical particle size 95 per cent finer than one micron, ground igneous rock (feldspar and flint) 50 per cent finer than three microns and metallic oxide colorants 90 per cent finer than one micron. The waste water contains approximately 1 to 2 per cent of this mixture and has a total volume of 50,000 to 100,000 g.p.d. Direct discharge continued until the agencies having jurisdiction over the river and General Electric Company officials realized that the waste load on the stream should be reduced.

In 1951, in compliance with company policy, a program was launched in cooperation with the Baltimore Harbor Board and the Maryland Water Pollution Control Commission to eliminate discharges of ceramic materials into the stream. The first step was to dredge a portion of the stream adjacent to the plant at a cost of $46,000. The second step was to build a 200 ft. retaining wall, costing $32,000, to keep dry solids from production operations reaching the river. The final step in the program was the provision of a treatment plant to treat future plant discharges.

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The Waste Control System

The Problem

There were three primary operating areas contributing waste materials to the plant effluent. The first was the batching and mixing section of the plant. Here the clays, feldspar and flint are blunged to a homogenous mix of 50 per cent solids and then dewatered in a battery of plate-and-frame filters to about 80 per cent solids. The filtrate, washings and tailings from these presses produce most of the waste. The second source of contamination was the glaze milling room where the same clays were used but in addition small percentages of finely ground metal oxides such as iron, chrome or manganese were added. The effluent from this area is primarily the water from the washings and tailings from the ball mills and other equipment. Due to the intenseness and opacity of the colorants these were probably the most objectionable wastes because the outlet for this discharge was in the vicinity of a small boat yard adjoining the plant. The third source of wastes was small quantities of solids originating in many scattered operations throughout the plant. The contamination, here again, came principally from the cleaning of equipment and disposal of small amounts of surplus glaze material.

The sanitary sewage from the plant passes through three septic tanks before discharging to the stream. This treatment is necessary since a city sewer is not available.

This was the problem before waste

treatment was undertaken. After it was decided that a waste treatment plant was necessary, a consulting engineering firm was retained to design a collection system and treatment plant for the industrial wastes to meet company specifications. Construction of the plant required from February to October, 1952. Manufacturing operations are similar to those before the treatment plant was provided.

The Collection and Treatment System

The waste collection system developed includes four sumps 6-ft. in diameter by 8-ft. deep plus three smaller sumps 2-ft. in diameter by 3-ft. deep, each located in the areas where the waste products originate. The water from each operation where solids escape is drained to one of the sumps as the first step in its collection. The larger of these sumps contains two pumps that operate alternately on float controls. The smaller sumps have one pump each, also utilizing the float control principle. Each of the pumps was originally equipped with a bleed-back for partial recirculation to prevent settling. During the interval in which the pumps are not in operation the amount of solids settled is not great and the bleed-back feature is not required.

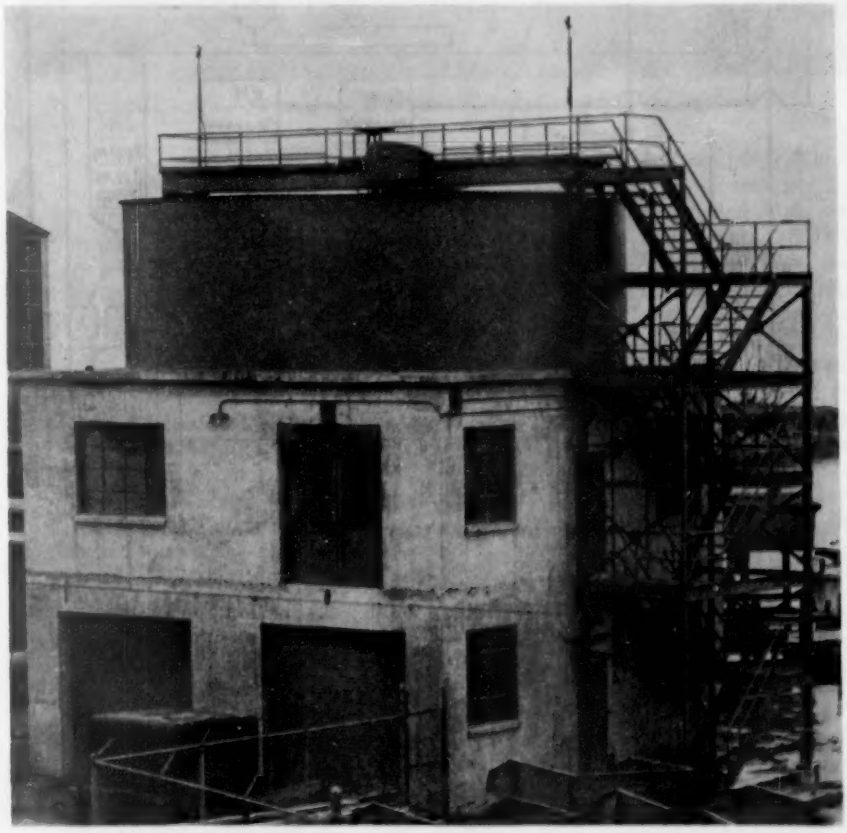

FIGURE 1.—Waste treatment plant for ceramic wastes at the Locke Department, General Electric Company, Baltimore, Md. Note portable dump bodies.

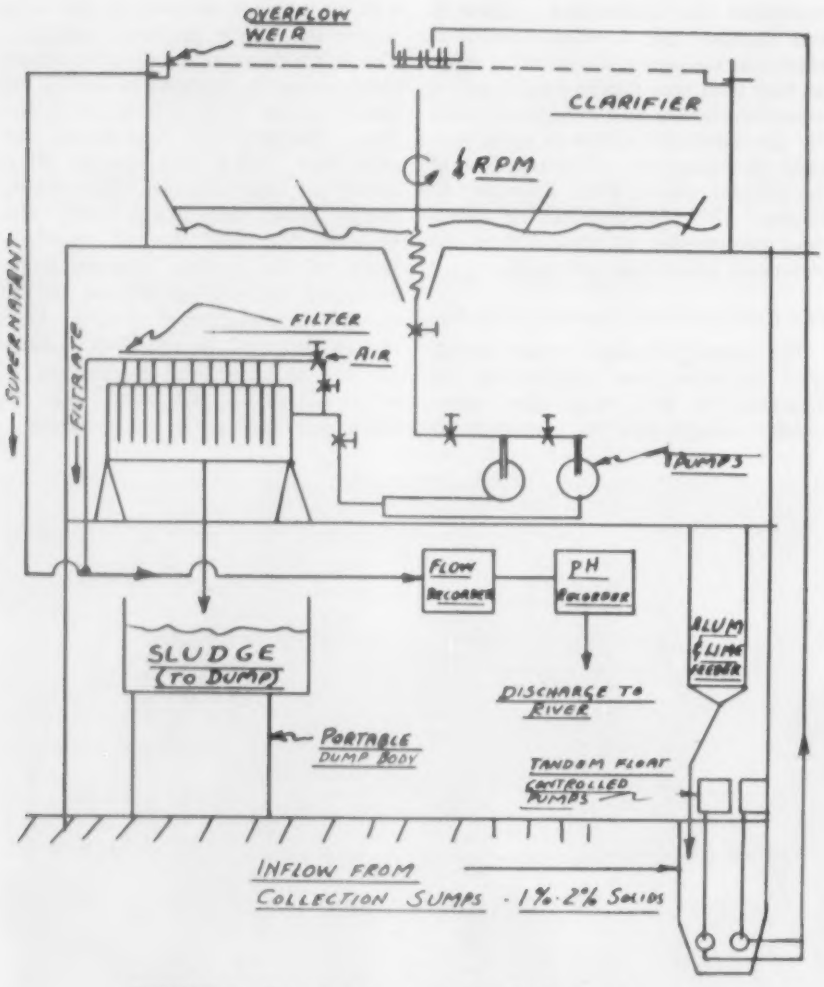

FIGURE 2.—Ceramic waste treatment, Locke Department.

Through a network collection system totaling about 1,400 ft. long, the effluent from the sumps is pumped to a central treatment plant. The collection system and treatment plant provides a single discharge at the extremity of the plant rather than numerous outfalls. The wastes arriving at the waste treatment plant (Figure 1) are collected in a central sump at ground level. Here the waste material is treated with a mixture of lime and alum (1:1 ratio by weight) for optimum flocculation and pH control. Figure 2 shows the treatment plant schematically. From here the waste is pumped to the third floor of the building into a 30-ft. diameter by 10-ft. deep clarifier that has a 12-hr. retention time. This clarifier permits the coagulated solids to settle to the bottom and be scraped into the sludge well. The effluent from which practically all solids have settled, overflows

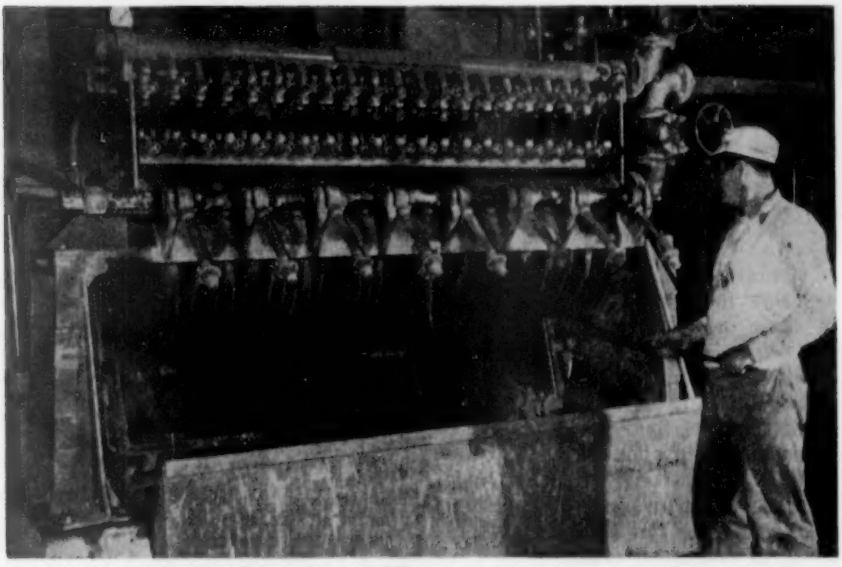

FIGURE 3.—Filter press from which sludge cake is being removed.

a circumferencial weir and discharges to the river.

The underflow sludge from the clarifier, containing 28 to 30 per cent solids, is pumped by one of two centrifugal pumps in parallel to a filter press (Figure 3). This filter was selected principally because personnel were already familiar with its use and because the filter cake is easy to remove. The unit contains 20 filter bags 30-in. in diameter and uses nylon filter cloths. Under normal operation it is necessary to discharge the press from 6 to 8 times per 8-hr. shift.

The filtrate from this press combines with the clarifier effluent and passes through an indicating and recording flow meter and pH meter before discharging to the river. The total cost of the treatment plant and collection system was approximately $120,000.

Operating the System

Initially some trouble was encountered in the operation of the clarifier in that the pressing time or turnover rate of the filter could not be predicted and, on one or two occasions, the clarifier became overloaded and was discharging an undesirable effluent. To prevent this condition from recurring, samples now are taken daily at 2 ft., 4 ft. and 6 ft. below the weir level. The appearance of an appreciable amount of solids at the 2-ft. depth indicates that more of the sludge must be removed by more frequent turnover of the filter. At the 4-ft. level the sample normally should be cloudy and contain approximately 10 per cent solids by volume. The check at the 6-ft. level indicates when the pressing cycle should be increased and the sample at this level is normally about 50 to 60 per cent solids by volume.

Problems were experienced initially with the filter in getting the material in the filter cake to release from the bags. This was corrected by using an air blow-back where the cake is first dried by forcing compressed air forward through it for 10 min. The air flow is then reversed to blow-back for one minute thus inflating the bags

TABLE I.—Average Characteristics of the Treatment Plant Influent and Effluent

Item	Influent	Effluent
Total solids (p.p.m.)	20,300	400
Suspended solids (p.p.m.)	20,000	100
Dissolved solids (p.p.m.)	300	300
Turbidity (Jackson) (p.p.m.)	5,000	100
pH	8–10	6–8

momentarily so that, upon subsequent deflation, the cakes can be freed either by their own weight or by a gentle assist from the operator. The cake, containing about 70 per cent solids, drops vertically through an opening in the floor to the bed of a portable truck body at ground level.

Table I lists an average analysis of the influent and effluent of the treatment plant and indicates the high removal of suspended solids.

The required treatment plant effluent quality was discussed with the Maryland Water Pollution Control Commission. In the interest of cooperating with the commission and keeping it posted on the treatment being accomplished, graphical summaries of daily laboratory tests are furnished each month.

To give details of the character of the treated effluent, graphs of the various determinations on the effluent for the month of September, 1954, are given as typical of normal plant operation.

Figure 4 shows the range of turbidity in the plant effluent which was less than 100 p.p.m. for the entire month. When the turbidity is less than 100 p.p.m., the exact value is not determined. This represents a decided reduction from the 5,000 p.p.m. typical of the influent to the treatment plant. It is gratifying that the turbidity continuously remains below the maximum of 300 p.p.m. set by the Commission. The upper portion of this graph summarizes the data from the pH recorder. Maximum and minimum values are reported here as "Daily High" and "Daily Low." This property of the effluent is now well within the state requirements.

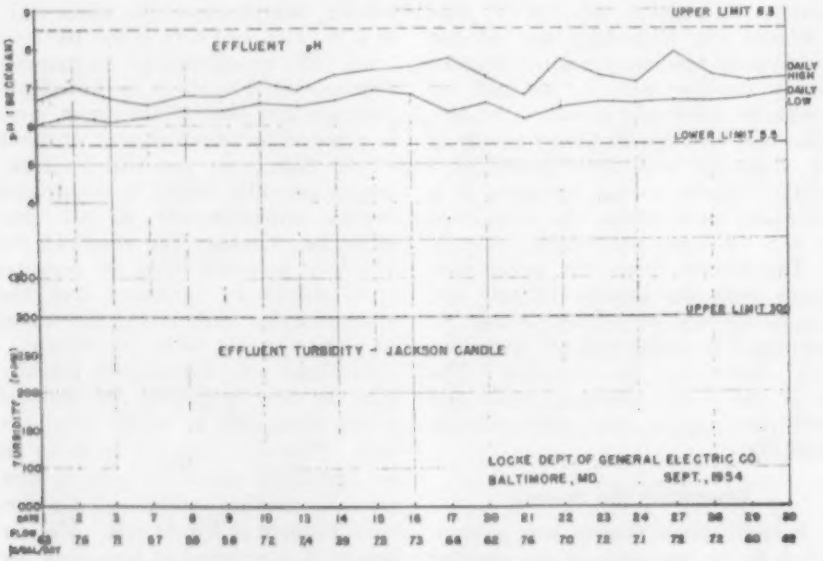

FIGURE 4.—Effluent turbidity and pH.

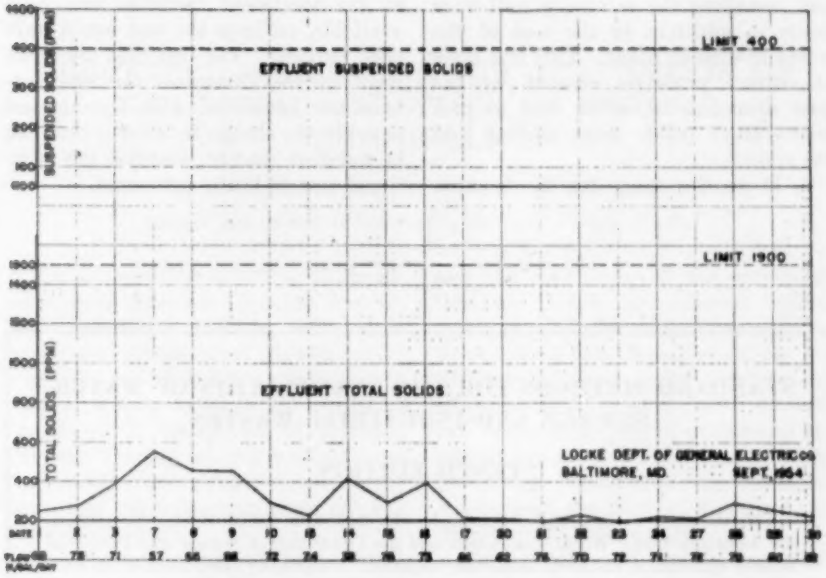

FIGURE 5.—Effluent total and suspended solids.

Figure 5 shows the total and suspended solids in the treatment plant effluent, but these characteristics are probably less significant than turbidity. The total solids range from 200 p.p.m. to 550 p.p.m. in the treatment plant effluent while the concentration of suspended solids was consistently less than 100 p.p.m. In addition, the effluent regularly meets state requirements from the standpoint of total and dissolved solids. The bottom of this graph shows the plant discharges between 55,000 and 76,000 g.p.d. for this month of operation.

Costs average $18,000 annually to operate the waste treatment plant, including depreciation. This annual cost is made up of $10,000 for operation and $8,000 for depreciation.

Summary and Conclusions

As a result of being able to look at the solution of the waste problem in retrospect, since the plant now has been in operation since October, 1952, the following conclusions appear pertinent:

1. Waste problems can be solved most expeditiously when the control agencies and the industrial representatives approach the matter jointly and on a completely cooperative basis.

2. This treatment unit in its two years of operation has treated the ceramic wastes from the Locke plant in a manner and degree that provides a completely satisfactory effluent to the Patapsco River. Based on operations contemplated for the future the treatment plant should continue to do a satisfactory job for many years.

3. Waste treatment at Locke is expensive because the treatment plant and collection system had an installation cost of $120,000. The operating cost for the approximately 75,000 gal. of wastes per day is averaging $0.66 per 1,000 gal. When depreciation is added the cost is $1.20 per 1,000 gal.

4. The expenditure for dredging the Patapsco River adjacent to the plant

and installing the retaining wall were made in addition to the cost of the waste treatment plant. This was done to correct problems created by the past discharge of solids and to prevent future solids from sliding into the river.

5. If greater space for the location of the treatment facilities had been available, perhaps the cost could have been reduced. The fact that the treatment in use eliminates the bad connotations associated with lagoons and delivers the sludge in a form that can be handled readily, justifies the additional cost to Locke personnel.

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SUGGESTED PROCEDURE FOR EVALUATION OF BIOLOGICAL OXIDATION OF ORGANIC CHEMICALS *

By E. J. Mills, Jr., and Vernon T. Stack, Jr.

Carbide and Carbon Chemicals Co., South Charleston, W. Va.

The analytical method for biochemical oxygen demand (B.O.D.) had its beginning about 1870 to 1890, when European investigators demonstrated that the biochemical reactions in natural waters could be correlated to the change in the amount of dissolved oxygen. During the intervening years the B.O.D. determination has developed into the best parameter for biological oxidation.

Investigators proved that B.O.D. data could be fitted to a unimolecular equation, and cumulative data indicated that a reasonably constant rate of biological oxidation could be expected for domestic sewage. This discovery was the foundation for the standard procedure for the B.O.D. determination, and the 5-day incubation period at a temperature of 20° C. was accepted as the standard expression of the quantity of B.O.D.

The adequacy of the 5-day B.O.D. value as a parameter for evaluating the strength of domestic sewage gave confidence that it might be used for industrial wastes. However, the reliability of the 5-day B.O.D. data for industrial waste was found to be questionable. Studies proved that for application of B.O.D. analyses to industrial wastes, the assumption of a relatively constant rate of biological oxidation for all samples was not valid.

The solution to this difficulty required the determination of velocity constants for biochemical reactions, and the expression of the concentration of B.O.D. as ultimate values rather than the formerly honored 5-day value. Less laborious procedures for determining the velocity constant and ultimate B.O.D. have been devised, but the convenience of evaluating the concentration of B.O.D. by the 5-day procedure encourages its continued widespread use and a disregard for the inherent deficiencies.

Over a period of several years laboratory personnel of the Carbide and Carbon Chemicals Company have studied the B.O.D. exerted by various organic chemicals. The cumulative data show that, in general, the B.O.D. exerted by an organic chemical follows one of the typical curves shown in Figure 1 when seeded with microorganisms from domestic sewage.

Curves Type I and Type II represent the exertion of B.O.D. where a fit of the data to the unimolecular equation is possible. Any misrepresentation of the concentration of B.O.D. can be avoided by determining the velocity constant, and the ultimate B.O.D. Obviously, any comparison of B.O.D. strengths based on 5-day values would be meaningless.

In several cases there is a persistent lag period in the development of the B.O.D. of an organic chemical with seed from domestic sewage. This is illustrated by curve Type III. The lag period complicates the evaluation of the velocity constant and the ultimate B.O.D. Thus, the 5-day B.O.D. value has no meaning. Any expression of the quantity of B.O.D. of organic

* Presented at 1954 Annual Meeting, West Virginia Sewage and Industrial Wastes Assn.; Huntington, W. Va.; Nov. 9–10, 1954.

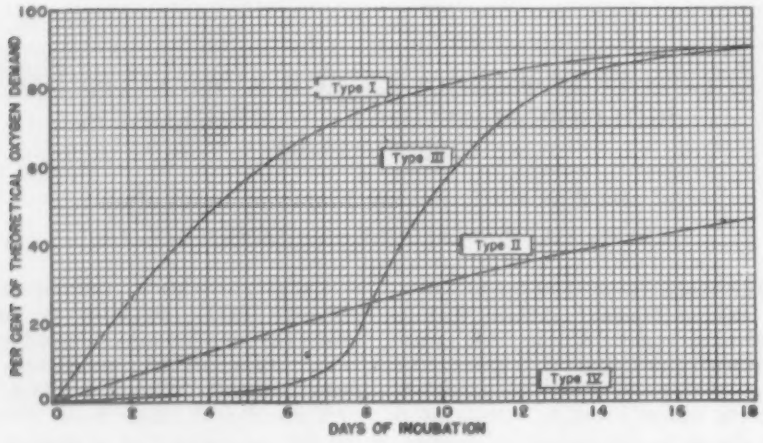

FIGURE 1.—Observed B.O.D. curves for synthetic organic materials seeded with sewage.

chemicals in this category must be in terms of ultimate B.O.D.

There are many organic chemicals that do not exert a B.O.D. when seeded with microorganisms from domestic sewage. Studies of the toxicity of these materials have shown that only a few are toxic to microorganisms. The majority apparently do not enter into biochemical reactions. Consistent results of this nature are convincing, but the lack of biological oxidation presents a challenge. Are the biochemical reactions suggested by the typical curves in Figure 1 to be accepted without question? Can the lag period in curve Type III and the absence of B.O.D. development in curve Type IV be assumed in evaluating the pollutional characteristics of these organic chemicals in a receiving stream?

Nature has her way of changing things to meet the need. Past successes with the acclimation of microorganisms, such as the treatment of formaldehyde by the Hercules Powder Company, cast a shadow of doubt on the finality of the data illustrated in Figure 1. Would acclimation of microorganisms and the development of suitable enzyme systems bring about different biochemical reactions and improve the B.O.D. development?

Extensive studies have been made of the acclimation of microorganisms for the oxidation of various organic chemicals. The majority of the attempts have been successful, but there are a few organic materials which appear to be highly resistant to attack by aerobic microorganisms. Selected examples of results from acclimation attempts were presented in a paper at the Ninth Purdue Industrial Waste Conference. Figures 2 and 3 show data included in the Purdue paper. The data in Figure 2 are for the oxidation of amines that do not exert a B.O.D. when seeded with microorganisms from domestic sewage. These data for acclimated microorganisms show a rate of biological oxidation very near the accepted normal. The data of Figure 3 show the improvement in the rate of biological oxidation obtained through the acclimation of microorganisms.

The major conclusion to be drawn from the data obtained with acclimated microorganisms is that the results of any biological oxidation are

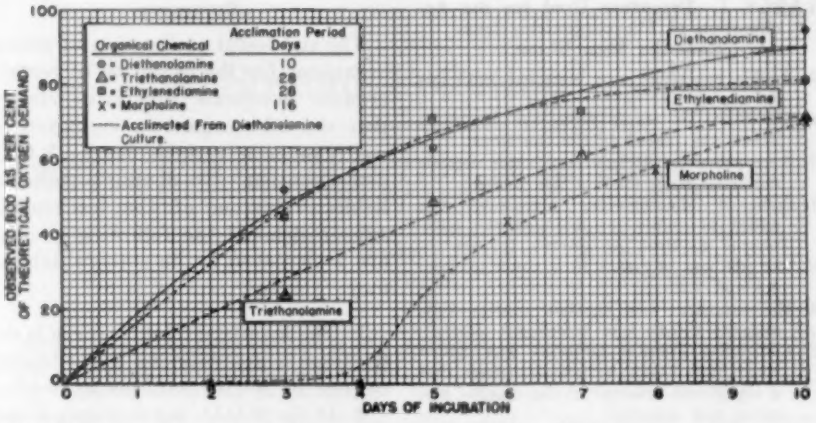

FIGURE 2.—Acclimation of microorganisms (from Kanawha River water) for amines.

related entirely to the ability of the microorganisms and the associated enzymes to bring about the desired biochemical reactions. There are probably many instances where bacteriologic growths from domestic sewage or an unacclimated source are not adequate or only partially adequate as seed for a B.O.D. determination. Where such inadequacies are realized acclimated microorganisms should be employed.

In any investigation of the possibility of treatment of a waste by biological oxidation the most suitable culture of microorganisms would be desired. The prediction of stream pollution should be more accurate in some instances if acclimated microorganisms were employed. In a stream receiving significant quantities of an organic material at least a partial acclimation could be expected to occur. This acclimation would very likely

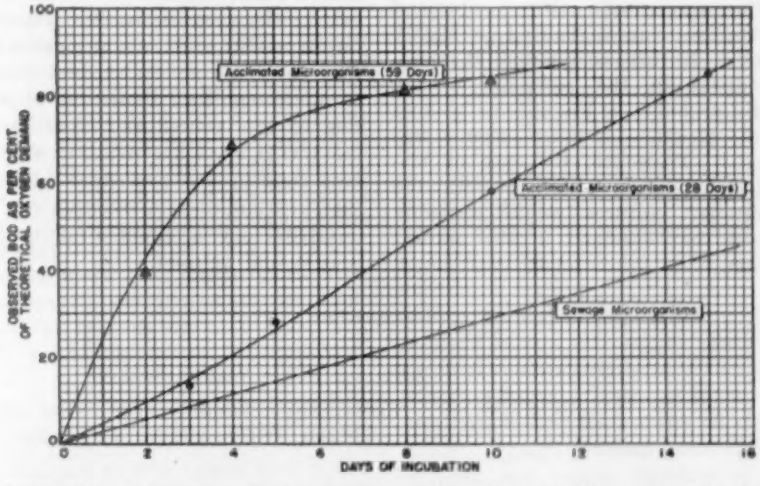
Acclimated Microorganisms (59 Days)
Acclimated Microorganisms (28 Days)
Sewage Microorganisms
OBSERVED BOD AS PER CENT OF THEORETICAL OXYGEN DEMAND
DAYS OF INCUBATION

FIGURE 3.—Acclimation of microorganisms (from Kanawha River water) for butyl carbitol acetate.

TABLE I.—Procedure Used for the Acclimation of Microorganisms from Kanawha River Water

1. A 6-l. container was supplied with air for aeration.
2. Six liters of water from the Kanawha River was placed in the container.
3. Approximately 50 p.p.m. of the organic material being studied was added.
4. Sufficient diammonium phosphate was added to supply the nitrogen and phosphorus required as growth factors.
5. The pH was adjusted to a value between 6.8 and 7.2.
6. The mixture was aerated continuously, and the C.O.D. was determined daily.
7. Additional organic material was added when the C.O.D. values indicated that a significant removal of the organic material had occurred.
8. Growth factors other than nitrogen and phosphorus were added by removing one-half of the liquid volume from the container once each week and adding an equal amount of tap water.
9. A portion of the acclimation mixture was employed as seed for a B.O.D. determination when the C.O.D. data indicated that development of a suitable culture of microorganisms had possibly occurred.

take place within the slime growths that exist on the bottom and banks of the receiving stream. These growths would then serve as a source of microorganisms for the waters of the stream.

The acclimated cultures obtained by the procedure in Table I are highly specific. Natural acclimation of microorganisms in the receiving stream would probably be less specific because of the presence of other organic materials. Therefore, the rate of biological oxidation obtained with the laboratory cultures would probably exceed that obtained in the natural stream.

Summary

The successful acclimation of microorganisms for the oxidation of certain organic chemicals illustrates clearly that the microorganisms employed as seed can be a variable in the B.O.D. determination. To obtain a more reliable evaluation of the biochemical oxygen demand the following procedure is employed in the authors' laboratory:

1. The long-term B.O.D. curve is determined employing an unacclimated culture of microorganisms as seed.

2. If the B.O.D. development is not satisfactory, the acclimation of microorganisms from Kanawha River water is attempted using the procedure in Table I. Acclimation is continued until a thoroughly acclimated culture is developed. If no acclimation occurs within 100 days, it is assumed that the material cannot be oxidized by aerobic microorganisms.

3. The long-term B.O.D. curve is determined employing the acclimated culture of microorganism as seed.

This procedure insures that a reasonable interpretation of the biochemical reactions can be made. Naturally the expenditure of a large amount of time in obtaining the desired culture of microorganisms limits the application of this procedure. However, if the B.O.D. data are required and the first step in the procedure indicates that unacclimated microorganisms are unsatisfactory, acclimated microorganisms should be used.

Stream Pollution

GROUND WATER POLLUTION FROM INDUSTRIAL WASTES *

By W. Fred Welsch

Senior Engineer, Nassau County Department of Public Works, N. Y.

The phenomenal growth in the population of Nassau County, Long Island, N. Y. coupled with the rapid industrial expansion has created a problem in protecting the ground water of the county from pollution. Industrial wastes from the many light industries locating in the area have created a critical situation in some sections.

Geology

Long Island, the largest island on the Atlantic coast of the United States, is entirely surrounded by salt water. Geologically, it is underlain by bedrock consisting of schists and gneisses. In Nassau county this rock formation is approximately 400 ft. below the shore line on Long Island Sound, sloping gently on an incline of 64 ft. per mile in a generally south-easterly direction to a depth of 1,500 to 2,000 ft. below sea level on the south shore along the Atlantic coast. The material between the rock floor and the land surface of the island consists of successive layers of sand and gravel aquifers of considerable magnitude and clay lenses of variable thickness. The aquifiers have tremendous storage capacity, serving as storage reservoirs for rain water.

Water Supply

The only source of water supply for utilization by public water supply systems and for private, industrial and agricultural purposes is from rainfall that averages 42 in. per year. Rain water and melted snow percolate through pervious subsoils into the sand and gravel aquifers. Less than 50 per cent seeps into the ground and the balance is lost by evaporation, transpiration and stream runoff into tidal waters.

Water that formerly was discharged into the ground from cesspools and septic tanks is carried off in sanitary sewers to sewage treatment plants discharging effluent into tidal waters, while new building has diverted more and more storm water into natural streams, pipes and culverts.

In line with conservation some storm water recovery is made possible by artificial ground water impounding and recharge basins varying in size up to 9 acres. These basins are strategically and hydraulically located at various places in the county, to permit a large percentage of the storm water runoff to percolate into the aquifer to replenish the ground-water supply.

This area possesses unique characteristics from a sanitary viewpoint because of its complete dependence upon water pumped from shallow and artesian wells. There are 50 public water supply systems serving the villages and water districts of the county.

* Presented at 1955 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York City, N. Y.; Jan. 20–21, 1955.

Industry

Industry is demanding larger quantities of water for cooling, processing, air conditioning and power purposes. Some industries have wells and others are supplied by public water supply systems. Industrial plants dispose of their wastes through recharge basins and diffusion wells (1). When permitted these wastes are discharged into sanitary sewer systems (2).

During World War II the quantity of hexavalent chromium wastes disposed of by recharging to the ground water through artificial recharge basins contaminated large segments of the ground water before the deleterious effects were detected (3). Chromium was used in aircraft industries for plating and anodizing purposes to enhance the corrosive resistant qualities of aluminum and other metals. An investigation disclosed that deep public wells and shallow private wells were contaminated. Water from one of the public water supply wells in close proximity to a contaminated area was found to contain over 1 p.p.m. hexavalent chromium. The use of this well was immediately discontinued. The industrial plants are now required to treat their waste material in accord with health department requirements, for the removal of chromium before the liquids are disposed to the recharge basins.

The chromium contaminated water was found to be moving slowly underground and apparently with some decrease in concentration (4). In an area immediately south of an aircraft company's seepage basin, chromium concentrations as high as 40 p.p.m. were discovered. The contaminated water covered an area 600 ft. wide by 3,600 ft. long, comprising about 50 acres. Samplings made 16 mo. after the original samplings seemed to indicate a slow movement of this slug to the south, together with some diminution in concentration probably due to dilution. The natural ground-water movement in the area is toward the south.

A continuation of the study revealed the presence of cadmium, a heavier and more toxic metal than chromium, in the ground water. Cadmium is utilized on a large scale in industrial plating operations. An analysis of the water in a recharge basin at an aircraft company plant indicated 1.2 p.p.m. of cadmium. The actual concentrations discharged to the recharge basin were probably higher than this amount, but due to the tremendous dilution through waste discharged from air conditioning and other purposes, the analysis showed a low concentration. A survey conducted on private shallow wells in the area disclosed that two of them in use at the time of the investigation contained 0.6 and 0.34 p.p.m. cadmium, respectively.

Test Well Program

Using the experience gained in previous studies of ground water contaminated by chromium, the Nassau County health and sanitation agencies initiated a thorough program of investigation on cadmium pollution. Field investigations were made in cooperation with the Nassau County Department of Public Works. Several series of 1¼-in. diameter test wells were driven on lines perpendicular to the direction of ground-water flow, just south of the recharge basins in question. A 4-in. diameter test well was driven at the site to a depth of 202 ft. to ascertain the nature of the subsurface materials. The log of the well indicated medium, coarse and fine sand and gravel at various depths and an impervious clay layer 72 ft. below grade. Samples were obtained by means of a soil sampler of the split steel tube type. A mechanical analysis was made of the pervious materials to determine hydraulic characteristics and permeability.

An attempt was made to determine

TABLE I.—Test Well Data for Cadmium Survey

Test Well No.	Well Depth[1] (ft.)	Cadmium Concentration						Depth to Water Table[1] (ft.)
		Upper Level		Maximum		Lower Level		
		Depth (ft.)[1]	(p.p.m.)	Depth (ft.)[1]	(p.p.m.)	Depth (ft.)[1]	(p.p.m.)	
1	55.4	—	—	entire depth	<0.05	—	—	10.0
2	50.5	13	<0.01	28	1.4	50	<0.01	9.7
3	50.1	18	1.1	31.5	3.2	50.1	1.8	11.6
4	50.4	18	0.44	45.0	1.95	50	1.3	11.6
5	45.1	—	—	entire depth	<0.05	—	—	9.7
6	50.5	13	<0.05	18	0.14	29	<0.05	10.8
7	50.3	—	—	entire depth	<0.01	—	—	11.0
8	58.8	18	<0.01	49	1.92	54	<0.01	10.2
9	55.6	13	0.07	34	1.3	50	0.86	11.7
10	44.3	—	—	entire depth	<0.05	—	—	11.2
11	55.7	13	0.04	29	1.85	50	<0.01	8.2
12	50.3	13	0.04	39	1.12	50	0.26	10.0
13	50.1	18	<0.01	34	0.11	44	<0.01	11.9
14	49.1	28	<0.01	38	0.1	49	<0.02	8.9
15	40.0	—	—	entire depth	<0.01	—	—	11.9
16	48.5	18	<0.01	28	0.17	38	<0.01	10.9
17	50.2	—	—	entire depth	<0.01	—	—	9.0
18	49.6	13	0.05	13	0.05	24	<0.01	8.6
19	49.3	—	—	entire depth	<0.01	—	—	4.9
20	50.5	18	<0.01	34	0.06	39	<0.01	5.2
21	48.7	—	—	entire depth	<0.01	—	—	4.6
22	49.0	—	—	entire depth	<0.01	—	—	6.4

[1] All depths indicated are from ground surface.

the width of the contaminated water strata, the depth where the cadmium was located and the horizontal course along which this contaminant was being carried by the natural ground-water flow.

The wells were driven by dropping a 200-lb. guided weight on top of 5-ft. coupled sections of 1¼-in. diameter extra-heavy drive pipe, the lowest section had a standard wellpoint attached to the bottom. By means of a pitcher type hand pump water samples were taken at 5-ft. intervals to an average depth of approximately 50 ft. The depth to ground water varied from 2 to 14 ft.

In several instances attempts were made to continue the well driving operation until a sample was obtained in which the contaminant was not detected. By following this procedure it was possible to determine both the vertical distribution and the elevation of maximum concentration of cadmium. Table I is a consolidation of the data on all of the driven test wells. The location of the test wells is shown in Figure 1. The extent of cadmium concentration covered an area of approximately 53 acres to a maximum depth of 60 ft. with concentrations as high as 3.2 p.p.m. The suspected origin of the cadmium was the recharge basins about 700 ft. north of the test area.

The east and west limits of the contaminated section are nearly parallel with a slight divergence as the cadmium travels southward under the influence of the ground-water flow. The most easterly and westerly test wells along the avenues perpendicular to the direction of ground-water flow did not contain significant quantities of cadmium. These borderline wells made it possible to establish the width of the contaminated

FIGURE 1.—Location of test wells for ground water contamination survey, Nassau County, N. Y.

area. Cadmium was not found in the creek south of the test well area. Other small areas in the county were investigated to detect the effect on the ground water of phenol, fuel oil, chlorine and the wastes from a gas manufacturing plant.

In accord with the classification and standards for underground waters adopted by the New York State Water Pollution Control Board (6), sewage or industrial waste disposal is not permitted within certain distances of a public water supply well or infiltration gallery used as a source of water supply for drinking, culinary, food processing or other purposes. Toxic wastes, deleterious substances, other wastes or heated liquids are not permitted in sufficient amounts to make the water unsafe, and if necessary, treatment of these wastes is required by the health authorities.

Conclusions

The discharge of plating wastes to the ground water is creating a hazardous situation in sections of Long Island. Every effort should be made to prohibit disposal unless the wastes have been treated to remove the toxic and deleterious substances.

Filtration of waste water through the soil structure described does not appreciably reduce the concentration of many chemical contaminants. The potential hazard to a surface and ground-water supply must be considered when contamination is present in the ground water upstream.

Many years may elapse before the effects of rainfall and ground-water dilution will eliminate these contaminants. Now, however, it will be possible to follow the contaminant in the course of its ground-water flow.

Acknowledgments

The laboratory work was conducted under the direction of Maxim Lieber, Division of Laboratories and Research of the Nassau County Department of Health, and field operations by Henry L. Frauenthal of the Nassau County Department of Public Works. The assistance of Terrance McCormack, Director of the Division of Sanitation, Nassau County Department of Health, is appreciated.

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DISCUSSION

By Maxim Lieber

Associate Sanitary Chemist, Division of Laboratories and Research, Nassau County Department of Health, N. Y.

Previous studies have established that the ground-water flow in this area is in a southerly direction. On that premise a series of test wells were driven on several perpendicular planes to the ground-water flow, just south of the recharge basin in question. An attempt was made to determine the width of the contaminated water strata, the depths where the cadmium was located and the horizontal course this contaminant was taking in its natural ground-water flow.

Figure 1 is a graphic illustration of well No. 2. This well is typical of the other driven test wells made during the investigation and shows a variation of cadmium concentrations at different elevations. In this well the maximum concentration was 1.4 p.p.m. at an elevation of 33.19 ft. above mean sea level (M.S.L.), with the lowest concentration of less than 0.01 p.p.m. cadmium at the highest and lowest elevations of the well.

The location of the driven wells has been indicated by Figure 1 of Mr. Welsch's paper. The four streets employed to develop the perpendicular cross sections to the ground-water flow were Lambert Ave., Fallwood Parkway, Plitt Ave. and Spielman Ave. As the cadmium contaminant flows in the ground under the influence of the ground water, it diverges, then flows in a somewhat parallel pattern and finally converges at Spielman Ave. under the influence of ground-water dilution. The pertinent data obtained from each of these

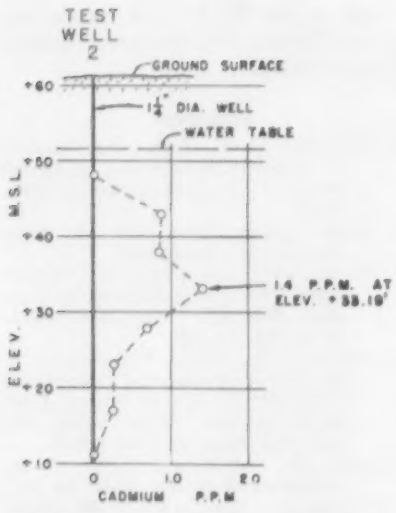

FIGURE 1.—Cadmium concentration of a typical well at varying depths below ground surface.

wells was utilized to develop the perpendicular cross sections to the ground-water flow at each of the four streets. These cross sections show the distribution of cadmium in the aquifer.

Figure 2 is the developed graphic cross section illustration of the aquifer at Lambert Ave. The most easterly and westerly wells (No. 15 and 5) did not contain any cadmium throughout their entire depth. These were called negative wells and gave the graphic limits of the contaminant on this perpendicular cross section. The other wells contained significant quantities of cadmium. Alongside each well are recorded the elevations where cadmium was first indicated, last indicated, and the highest concentration that was found. In well No. 3, the highest concentration of cadmium detected in the entire investigation was 3.2 p.p.m. at a depth of 31.5 ft. This was expected because the least amount of ground-water dilution occurred in this first cross section.

On the basis of the information available, it was practical to indicate the probable extent of this cadmium infiltration by the broken line. This is the segment of cadmium contaminated water flowing in the ground as a part of the ground-water flow.

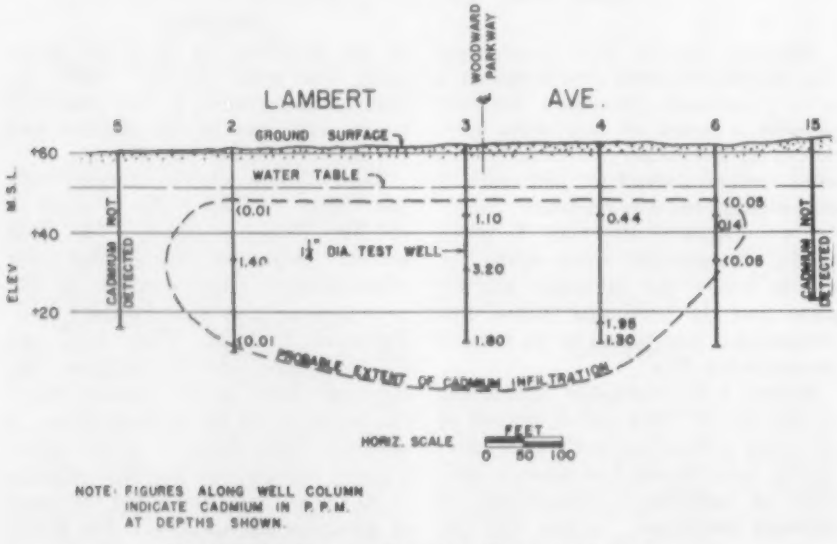

FIGURE 2.—Cross section of aquifer at Lambert Ave.

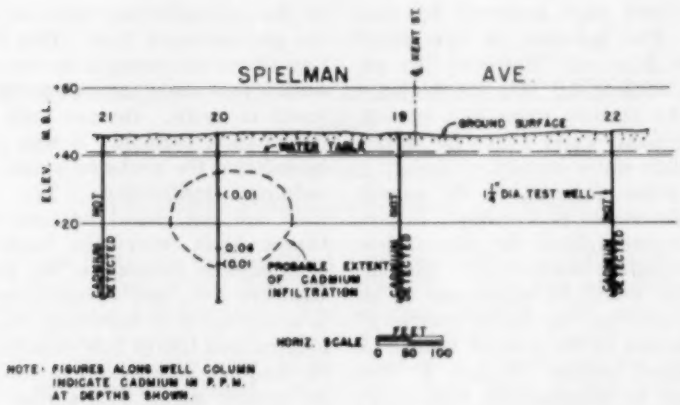

FIGURE 3.—Cross section of aquifer at Spielman Ave.

Similar perpendicular cross sections were developed for Fallwood Parkway, Plitt Ave., and Spielman Ave. At Spielman Ave. (Figure 3) the effects of ground-water dilution are plainly evident. Only a minute quantity of cadmium was detected in well No. 20; 0.06 p.p.m. at a depth of 34.0 ft. Therefore, the probable extent of the cadmium infiltration at this last section was enclosed by the broken line around well No. 20.

It is interesting to note the most southerly aquifer cross section at Spielman Ave. is just above Massatayun Creek. Although this creek is influenced by surface runoff, it is undoubtedly affected by ground-water conditions. Massatayun Creek eventually flows into Massapequa Pond and finally Massapequa Lake. The New York City water supply system obtains water in this area for emergency or auxiliary purposes. The city utilizes the waters of Massapequa Pond, driven wells in the area and infiltration galleries located south of the pond. Samples of water from Massa-

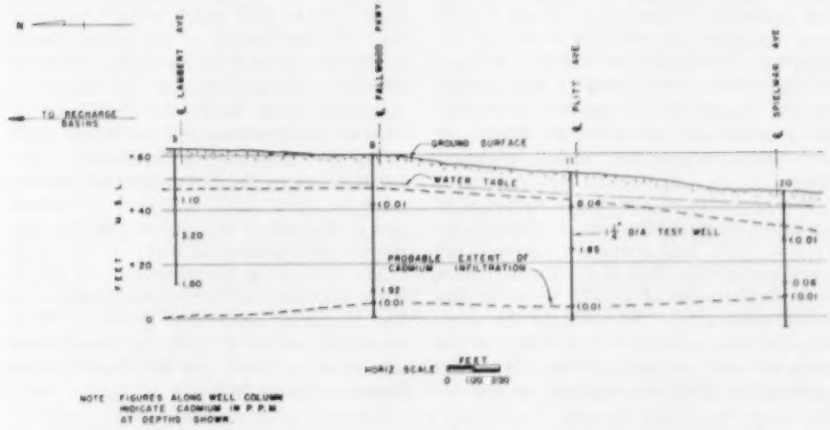

FIGURE 4.—North and south cross section developed from the maximum cadmium concentrations in the aquifer cross sections.

tayun Creek were analyzed for cadmium. The presence of this metal was not detected. However, the potential hazards of this contaminant cannot be ignored when it is present in the ground water above the source of a public water supply.

The prime interest of the survey was to determine as accurately as possible the geographical direction of flow of the cadmium contaminant. This information would be significant as an aid in following the future course of the cadmium in the ground water. A longitudinal section (Figure 4) was developed by utilizing the location of the maximum cadmium levels in each of the perpendicular cross sections of the ground-water flow. This illustration shows the changes in the ground surface and water table elevations from north to south. On the basis of the information available it was possible to indicate the probable extent of the cadmium infiltration. The dashed lines are not closed because the recharge basin where the trade waste originates is located to the north of Lambert Ave., and Massatayun Creek is to the south of Spielman Ave. This longitudinal line of flow coincided with the findings of previous investigations on ground water flow studies in the area.

PENNSYLVANIA ASSOCIATION EULOGIZES TED MOSES

The highlight of the meeting of the Pennsylvania Sewage and Industrial Wastes Association at State College, Pa., August 22–24, 1955 was a surprise "This is Your Life" presentation on August 23 honoring Howard Eugene "Ted" Moses.

In 45 minutes of "Ted Moses Night," the life of the first secretary of the Federation was illustrated by slides, tape recordings, and personal participation by several persons. These included his family, friends and professional associates. Credit for the most successful presentation is due the Association Committee which made primary arrangements for it. Much credit is also due Dr. George E. Symons, who assisted in the preparation and acted as Master of Ceremonies to give the "show" maximum effect.

The life story of Ted Moses started with a picture of his birthplace in Muhlenberg, Pa., in 1875, and continued through his many accomplishments in the Pennsylvania State Department of Health which he has served since 1908. Woven into the story were personal anecdotes and notice of his many services and recognitions. An 1898 graduate of Dickinson College, he has received the Honorary Degree of Doctor of Science from his Alma Mater. Now retired from his duties with the Department of Health, Moses continues to serve the Commonwealth as consulting sanitary engineer. At the conclusion of the presentation, the color slides, a viewer, and the "This is Your Life" volume were given to the honored guest.

Among his many contributions to Federation activities is his service as Secretary from 1928 to 1941 which is truly outstanding. He had served on the organizational Committee of One Hundred and filled the secretary position during the important formative years under the Presidency of Charles A. Emerson (whose recent death is reported elsewhere in this issue). During these years the Federation membership grew to about 3,000 affiliated individuals and at the end of this period full-time employees were needed to carry on the work.

The Federation has recognized the superlative character of the service rendered by Ted Moses by conferring Honorary Membership upon him in 1943, the Kenneth Allen Award in 1945, and the Charles Alvin Emerson Award in 1951.

THE SPREADING OF SINKING PARTICLES IN THE SEA

By Fredrik Beyer

Universitetets Biologiske Laboratorium, Oslo, Norway

The sewage from Oslo is discharged to the harbor region of the Oslofjord following primary sedimentation. The resulting sludge is removed in a tank barge and dumped into the fjord. During the summer season, when thousands of people are bathing in the inner fjord, the sludge is dumped between Tofteholmen and Mölen islands (Figures 1 and 2).

In the summer of 1954 the municipal authorities of Oslo investigated the effect of this sludge dumping. The author was engaged in carrying out the field and part of the laboratory work. The chief objective was to check the number of bacteria, in particular the number of fecal coli, in the surrounding surface waters. Hydrographical studies were also included. Currents were observed through the use of drogue-shaped indicators made of plates of galvanized iron, which were dropped behind the barge during dumping. By means of a thin cable of desired length the cross of sheet metal was connected to a small buoy with a flag. Strong wind and the flow of the upper surface water may have modified slightly the drift of the indicators.

The maximum tidal range in Oslo is 24 cm. As a rule, a pronounced eastward component is found in the surface current, due to the discharge of the large Drammen River. This river and others are responsible for the low surface salinities. Most frequently, a density discontinuity layer was found at a depth of about 7 m.

The contents of the barge were of a mixed nature, and varied from time to time. Some of the particles were rather heavy and sank to the bottom rapidly. This was confirmed by the shrimp trawlers, who complained of the amounts of "disgusting" particles that were adhering to the meshes of the trawl when it was used in the dumping area. On the other hand, some of the material sank so slowly that in some cases it could be found in the surface water four hours after the dumping and at a distance of 3–4 km. from the dumping place.

It is remarkable that the "cloud" of polluted surface water remained rather concentrated for such a long period of time. However, with a strong wind, the area of surface water containing particles from the dumping was greatly enlarged. In calm weather, the cloud of polluted surface water moved faster than the current indicator at the one-half meter depth. With wind velocities exceeding that of a gentle breeze, the cloud of sludge particles moved slower than this indicator.

The question arose whether or not there was a subsurface connection between the mass of sludge sinking at the dumping place and the drifting surface cloud. Although excellent for the study of bottom deposits the echo-sounding apparatus on board the vessel hired for the investigations was not able to tell what became of the sludge after having been dumped. On the recommendation of the author, observations were also carried out from the air by means of a helicopter.

The sea water reflects practically no light and appears black or very dark blue when seen from directly overhead. Numerous small particles in

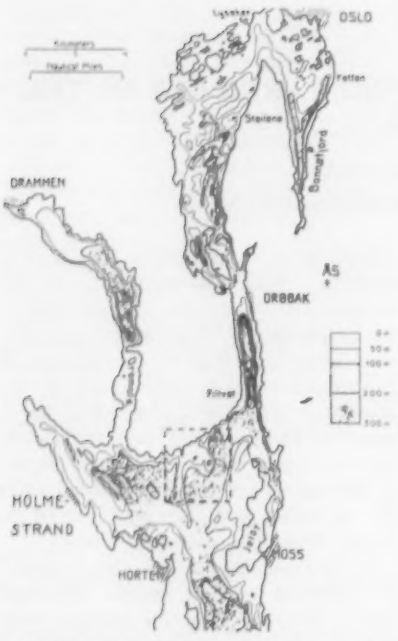

FIGURE 1.—Oslo and its fjord. The sludge dumping area is inside the dash lines.

the sea scatter the light in such a way that the sea appears lighter.

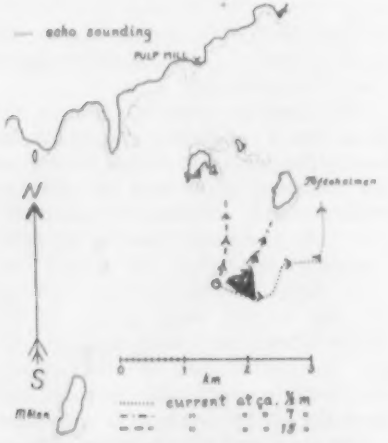

FIGURE 2.—Details of the area enclosed by dash lines in Figure 1. The shaded area is the sludge dumping site with arrows indicating path of current float indicators.

Larger objects, as well as foam, reflect considerable amounts of light and appear light against the dark background of the sea. The direct rays from a bright sun substantially increase the visibility in the sea. On September 1, 1954 when the helicopter cruise was made, the sun only intermittently penetrated the thin stratum of clouds and was never perfectly bright. Moreover, due to overloading of the aircraft, it was almost impossible to attain the desired height for taking survey photographs. Therefore, they had to be taken at an angle and consequently the contrast in the photographs was reduced by light reflected from the sea surface. Polarizing filters and glass spectacles, would have improved the results of this expedition. Nevertheless, the photographs turned out more than satisfactory.

Figure 3 shows that although there seemed to be no discontinuity layer on this occasion, the increase in density with depth was indeed pronounced. Below 25 m. there must have been a considerable increase in the viscosity of the water. Therefore, reduced sinking velocity of the particles below the surface must be expected. According to the tide tables, high tide occurred at 7:41 PM. The sludge was dumped and the indicators dropped at 2:35 PM within the area marked by the small circle in Figure 2. The arrows indicate the hourly positions of the indicators. The shaded area is the cloud of sludge particles, as seen from the air 55 min. after dumping. At the time of dumping the weather was calm. Later there was a light, southerly wind which after one hour increased to a gentle to moderate breeze.

Figure 4 shows the actual dumping, during which the barge moved in a southerly direction. The polluted surface extends as a band about 15 m. wide and 130 m. long, covering an area of approximately 2,000 sq. m. It should be noted that domical struc-

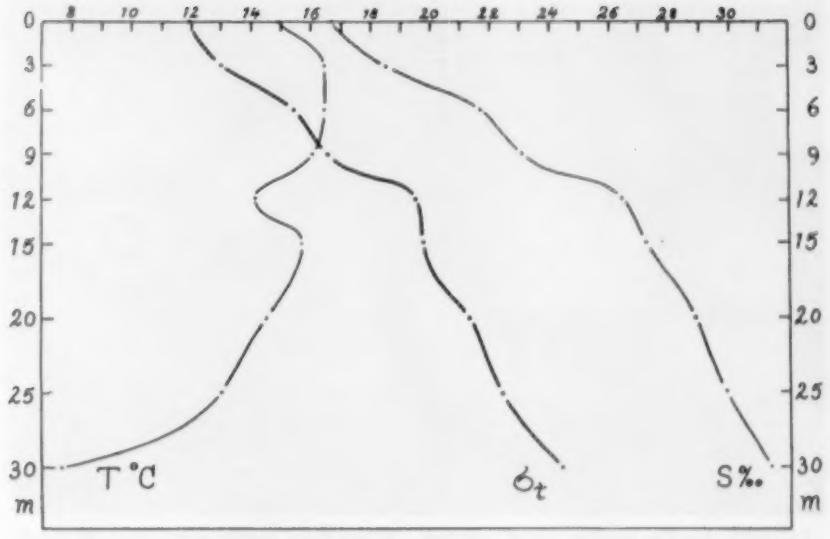

FIGURE 3.—Temperature, density and salinity of the water at the sludge dumping site on September 1, 1954.

tures, valleys, etc. appear only on the cloud surface when it is covered by clear water. When the cloud of particles extends to the surface of the sea it does not have topographical structures and therefore appears diffused. In Figure 5, only the foremost diffused part of the cloud is at the sea surface. The research vessel is in clear water which has moved in from the area in front of the picture. The sludge is settling with a flat slope.

Due to differential currents the sludge cloud became extended in a southeast-northeast direction (Figure 2). A southerly wind extended the eastern edge of the cloud towards the north. This resulted in a triangular shape cloud. Fifty-three minutes after the dumping the visible cloud of

FIGURE 4.—Sludge barge discharging.

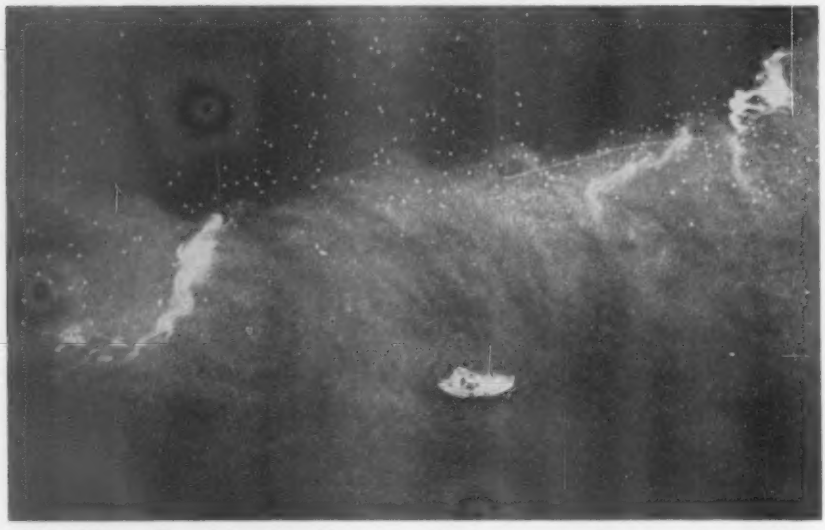

FIGURE 5.—The sludge "cloud" settling. White foam marks upper edge of cloud particles, vessel floats in clear water. White specks are sea gulls.

sludge particles covered nearly 90,000 sq. m.

The cloud of sinking particles was recorded by the echo-sounding equipment (SIMRAD) as another research vessel moving in a northeasterly direction passed the 7-m. current indicator about 1¾ hr. after the sludge dumping. This record presented proof of the presence of the cloud. Echo-sounding equipment sensitive enough to detect dispersed sludge should be considered for use in making investigations of this type.

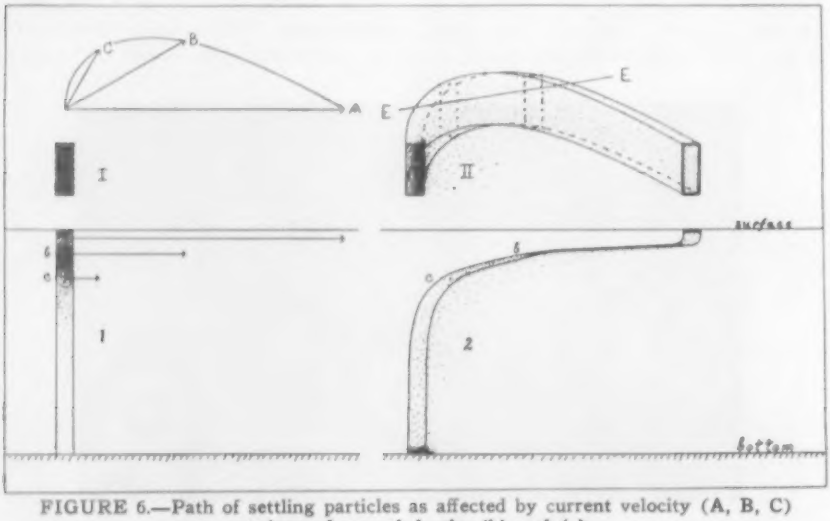

FIGURE 6.—Path of settling particles as affected by current velocity (A, B, C) at the surface and depths (b) and (c).

FIGURE 7.—Distribution of pulp mill waste products (light area).

In Figure 6 the dots represent sewage particles in a simplified hypothetical case. The arrows (A), (B), and (C) indicate the direction and velocity of the current at the surface and at the depths (b) and (c) respectively. The line E–E indicates the part of the cloud traversed when the echo-sounding record was made. The current should decrease toward the bottom according to the smooth curve connecting the arrows. The horizontal and vertical projections of the polluted water column immediately after the dumping are represented by (I) and (1). Projections of that same water and particles after one time unit are represented by (II) and (2).

In order to emphasize the mechanisms that are active, the increase in density with depth should occur within a well defined discontinuity layer or pycnocline. Such a density distribution is often encountered in Norwegian fjords, including the Oslofjord. When the density increase is at a maximum, the eddy viscosity and the friction are at a minimum. It follows that the discontinuity layer is also the level where the greatest changes in velocity and direction of the current are found. Whereas the pycnocline is the level where sinking particles accumulate, it is also the level where they are spreading horizontally. As the spreading of the cloud progresses, the veil of suspended particles becomes very thin and eventually hard to discern. A strong wind with waves will greatly increase the area of the polluted surface.

Figure 7 shows the distribution of waste products (sulfite liquor with cellulose fibers) from the pulp mill indicated in Figure 2. The waste liquor is discharged just outside the left hand margin of the photograph. The bottom of the fjord is not visible.

The science of photogrammetry is well established and the application of aerial methods to pollution and marine studies should not be neglected. Even the vertical current indicator flags were much easier to find from the air than from the boat. Moreover, surface water samples could have been obtained directly from the helicopter with the greatest of ease. If only sur-

face samples were desired, work could be accomplished from the helicopter in one day that would have taken a week with the use of a surface vessel. However, rough weather would have had to be avoided. With a polarizing filter and a proper color filter, the camera will by far excel the human eye in discovering suspended matter in the sea. Perhaps the method will make possible a rapid and large-scale localizing of areas of phytoplankton mass production and zooplankton swarms.

NON-MEMBER MEETINGS OF INTEREST

The 83rd annual meeting of the American Public Health Association will be held November 14–18, 1955 in the Municipal Auditorium, Kansas City, Mo. The general theme of the meeting is "Where are we going in public health?" Details are available through APHA headquarters, 1790 Broadway, New York 19, N. Y.

The Nuclear Engineering and Science Congress will meet December 12–16, 1955 in Cleveland, Ohio. This first meeting of its kind will be held in conjunction with the International Atomic Exposition and will feature outstanding papers and exhibits covering practically every phase of peace-time uses of atomic energy and its by-products. The Congress is sponsored by the American Institute of Chemical Engineers and 24 participating groups. Details may be secured from the Atomic Exposition office, 931 Book Bldg., Detroit 26, Mich.

USPHS APPOINTS SANITARY ENGINEERING RESEARCH GRANTS OFFICER

The appointment of Harry A. Faber, New York, as Sanitary Engineer Research Grants Officer effective July 1, 1955 was announced by the USPHS.

Mr. Faber will assist the Public Health Service in developing the research and fellowship grant program as it relates to scientific investigations in the field of sanitary engineering. He will work closely with the National Institutes of Health and the Robert A. Taft Sanitary Engineering Center.

Mr. Faber leaves the position of managing editor of *Water and Sewage Works* magazine, which he held for the past three years. Prior to his editorship he served the Chlorine Institute, Inc., New York from 1935 to 1952.

THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

SOMETHING TO THINK ABOUT

Alfred E. Perlman, President, New York Central Railroad has been quoted as saying, "After you've done a thing the same way for two years, you should look at it carefully. After five years, look at it with suspicion. After ten years, throw it away and start all over."

Does this apply to your operations in sewer maintenance or treatment plant? Perhaps someone may argue that it takes two years to get the "bugs" out of a new plant and after five years there has been such a population growth or change in the character of the wastes that operation no longer reflects design conditions. After ten years is it time to throw the plant away and start all over? It is true that a constant change in conditions is occurring at many treatment plants. However, all of us need to stop and give some careful imaginative thought to our methods of operation.

Many activities have been performed for years with little or no thought to change or improvement. It is frequently easier to do things in the same old way than it is to shake ourselves out of the lethargy of complacency. An interesting occupation is one that provides room for improvement and change. Is the sewage treatment field so uninteresting that change is not possible? It certainly has not reached a state of perfection.

Perhaps those in all phases of the profession—design, equipment and operation, should ponder on the words of Alfred Perlman and change some of the concepts of sanitary engineering, particularly in the field of sewage and industrial wastes. We've had new ideas in equipment, in digestion, and in other aspects but basically we are doing things the same way we did,—not 5 or 10 years ago, but 25 years ago.

Sit down this evening and consider your job with all the imagination and inquisitiveness possible. Jot down the resulting thoughts and tomorrow start something new. D.P.S.

LET THE PEOPLE KNOW *

Making use, in a publicity sense, of the interest the public shows for large construction projects is not a new idea. But, by and large, the idea has been reserved for big projects. Now from one Canadian town comes what seems to be a praiseworthy twist to the original idea. The water department of that town places signs at all the jobs it has in hand (the sewer department could, too). These tell the public what is being done, why it is being done, the estimated duration of the job and how much it will cost.

There are various points about this that commend themselves. In the first

* Condensed from the *Bulletin*, Western Canada Water and Sewage Conf., 5, 3 (June, 1955).

place, it is a municipal department which is doing the construction. People like to know what is going on and anything that is being done for the common good of all will be of particular interest. Secondly, since the work is a municipal undertaking, the sidewalk superintendent has a proprietary interest in it. The taxes he pays are contributing to the work. Lastly, there is the matter of civic pride. Both townspeople and visitors can see how the town is developing.

Basically, people are curious and, provided the information is brief and easily read, a good large notice board is all that is required. So many things are going on all the time in the city, town and village streets, that this could be a very effective way of letting the man in the street see for himself how his money is being used.

THE RESPONSIBILITY OF THE ADMINISTRATOR AND OPERATOR*

By Eric V. Quartly

Superintendent, Sewage Treatment Division, Department of Public Works, San Diego, Calif.

In the average growing community the operation and maintenance of the sewage treatment facility is an important municipal function. The welfare, health and happiness of the citizens depend, to a considerable degree, on successful plant management.

However, in too many municipalities this is not always accomplished. Frequently there is a serious lack of understanding and a feeling of apathy between the administrator and the sewage treatment plant operator in the general concept of their responsibilities to each other. Unfortunately, in many instances, no attempt is made to resolve or define these responsibilities until demoralizing frustration and misunderstanding have been experienced by both the administrator and the operator. If efficient and economical plant operation is to be obtained and management is to be successful, it is essential that the responsibilities of both the plant operator and the administrator be clearly defined, and the problems confronting each be fully understood by both parties.

Several years ago, during a visit to a sewage treatment plant, in a small but modern northwestern community, the operator on duty was asked the number of personnel employed at the plant and how many hours per day they worked. The operator advised that he was the only employee and that he worked six days a week and received a one week vacation annually with no allowance for sick leave. He further explained that during his absence the chief of police assigned one of his patrolmen to take care of the plant. In this case, it is evident that the administrator did not realize his responsibility to the operator or the community, since he failed to provide properly qualified relief personnel to operate the plant during the absence of the regular operator.

During the inspection, the operator took great pleasure in pointing out the features of the plant. A climb to the top of the fixed-cover digester, brought comments on the numerous white stains on the roof. The operator explained that always after drawing sludge to the drying beds, he mixed a batch of milk of lime solution to dump into the digester to assist in

* Presented at 1955 Annual Meeting, California Sewage and Industrial Wastes Assn.; Riverside, Calif.; April 27–30, 1955.

re-establishing digestion. Further conversation regarding this problem, disclosed the fact that when the operator discharged sludge to the beds, the digester was emptied almost completely, and of course, had no good sludge left for seeding purposes. The operator used poor operating techniques and periodically created a hazardous situation at the plant due to ignorance of safe practice. Certainly he did not fulfill his responsibility to the administrator.

The above examples are, perhaps, somewhat extreme and are not wholly representative of existing practice, but they serve to illustrate the need for cooperation by the operator and management.

Responsibilities

Obviously, the degree of responsibility that the administrator and the operator have to each other, will vary with the size of the treatment plant and the particular type of municipal government under which they operate. The general apathy on the part of plant operators and the laissez faire attitude of the administrators appear to be more pronounced in the smaller communities. This situation probably exists because the administrators fail to appreciate the importance of efficient plant operation and the extent of the operator's responsibilities. Likewise the plant operator possibly is not as well qualified for his job as he should be, partly due to a lack of qualification requirements at the time of appointment. In addition, his method of operation may not be challenged except on rare occasions. However, in any employer-employee relationship, there must be a mutual understanding of the objectives and requirements of the job to be done. Each has the right to expect fair treatment from the other.

Administration

One of the most important responsibilities of the administrator is to see that the operator is provided with sufficient funds to adequately operate and maintain the sewage facility. The administrator, in turn, has every right to expect the operator to use sound judgment and prudent economy in the expenditure of these funds. The operator should have the right and opportunity to make known his needs to plant management. It is the duty of the operator to keep the administrator fully advised on approaching major problems in maintenance and operation so that the administrator will have this information available for administrative use during budget preparation and for periodic reporting to the legislative body. The operator must realize that he is probably the only individual who is in a position to know or forecast, with any reasonable degree of accuracy, the needs and future requirements of the plant and the administrator expects the use of sound and intelligent planning on the part of the operator.

The operator expects the administrator to see that he is paid a salary in line with the responsibility entrusted to him and that he is provided with decent working conditions, proper tools and safety equipment with which to do his job. Authorities on human relations have determined that all men engaged in industrial work need to enjoy job security and a harmonious relationship with their employers. Sewage treatment operators are no different in this respect. They too need the job security and knowledge that they are an important link in the municipal management. Therefore, the operator needs to know that the administrator considers the operator's job an important one and that he is receiving the necessary moral support from top side. The administrator should make it a point to pay periodic visits to the sewage treatment plant to observe operation and discuss mutual problems with the operator. Likewise, the operator should be free to go to the administrator with

special problems that he is unable to solve by means at his command.

Operation

Quite often, the operator fails to win the respect and support of the administrator because of inefficient operation. If the operator has not qualified himself for his job he should not expect to receive recognition from management. The operator has the basic responsibility to see that he performs a good job of operation and keeps himself continuously informed on the best operating and maintenance practices. He should also participate in short schools, when available, and he should subscribe to, and regularly read, several of the periodicals that cover the field of sewage treatment. Generally, the administrator will be glad to secure this reading material with municipal funds, if he knows it will be put to good use and retained for reference purposes.

It is also the responsibility of the operator to keep accurate records of the various plant activities. These records might include a log of operating problems and maintenance overhauls, a lubrication schedule and other pertinent items. A resume of this information should be forwarded periodically to the administrator. The information should be neatly prepared with helpful explanations where needed to assist in explaining the data.

Summary

To summarize the responsibilities that the administrator and the operator have to each other, it might be said that each must realize the need for fulfilling his obligation to the team. The administrator is expected to provide the operator with satisfactory working conditions, sufficient funds to adequately operate and maintain the plant, a decent salary, the necessary moral support and the right to discuss mutual problems. On the other hand, the operator is expected to do an efficient, economical job in operating the sewage treatment plant and he has the obligation of keeping himself well informed on new and better methods of treatment and maintenance. Finally, the operator has the responsibility of providing the administrator with accurate, factual information regarding plant deficiencies and future problems.

LIFT STATION AND GRIT CHAMBER FORUM *

PHILIP SEAGER, *Leader*

Superintendent, Sewage Treatment Plant, Winter Haven, Fla.†

Lift Stations

Chairman Seager:—If it were not for grit, sand and odors the sewage treatment plant operator's job would be much simpler. The high temperatures in Florida during many stages of sewage treatment are beneficial, particularly in digestion and secondary treatment processes, while in lift stations, they aggravate the odor problem. The longer sewage is held under high temperature conditions, the worse it becomes. Lift stations come first because they will help the lines and treatment plant and naturally, come before the grit chambers, although many lift stations now are being designed to include the grit chamber. However, in most cases lift stations are ahead of grit chambers that are located at the treatment plants.

* Presented at 1954 Annual Meeting, Florida Sewage and Industrial Wastes Assn.; St. Petersburg, Fla.; Nov. 8–10, 1954.

† Presently Sanitary Engineer, Bureau of Sanitary Sewers, Tampa, Fla.

John Greenleaf, Sanitary Engineer, Rader Engineering Co., Miami, Fla.: —The point just brought out on the climate in Florida adds greatly to the operator's problems at the treatment plant. Although the temperature does improve certain treatment processes, in lift stations it creates one of the biggest problems. Lift stations must be located throughout the sewer system at strategic points, usually at the bottom of a hill, then the sewage must be pumped either to the next lift station or the treatment plant. It is a problem where to locate these low points. There seems to be a general antipathy on the part of the public to have anything connected with sewage located near their particular residence. It is a task for the designers to plan a lift station that, first, will not look like a sewage pumping installation and second, will function properly and generally do the job expected.

One of the problems that has always been a plague to the designer, is the problem of trying to take out at the lift station the solids that accumulate or come through with the sewage and might otherwise clog the pumps. Problems of solids removal by screening at a lift station located in a residential area is not only a problem to the operator, but it can cause a certain amount of nuisance. I think the advent of the screening grinder has gone a long way in helping that problem, particularly in the larger pumping stations. On some smaller stations the work that has been done by various pump companies in the development of pumps that merely push the solids through the station are definite steps forward. For years the small lift station has been a problem. The most satisfactory solution has been the ejector pot which merely takes whatever comes and pushes the solids along the line.

At the larger station pumps with greater capacities present the problem of designing wet well facilities so the pumps can be handled and maintained with minimum difficulty. The provision of access to the equipment has always been an important consideration in the design of stations and the proper sizing of pumps. Where it is desirable to be sure that in the event of failure any one item of equipment will handle the total flow the pumps should be as large as possible. There is the difficulty on the other end of the line of getting slugs of sewage into the treatment plant when the operator wants the flow to be as uniform as possible. The opposite is to pump at a more or less uniform rate with sewage backing up into the sewers. The designer usually tries to obtain a proper balance between these various factors.

The problem of overflow is another item that gives the designer quite a headache, particularly in flat country where there is no place for an overflow. Then it is a question of what does one do for either auxiliary power or auxiliary pumping. Somehow or other the dollar always seems to be in the foreground. These are just some general thoughts on sewage pumping stations.

Chairman Seager:—Mr. Greenleaf mentioned the difficulty in getting money to do things with; the public and state officials are very loathe to part with money to do things the way they should be done. Now, I wonder if it isn't the consulting engineer's responsibility to insist on at least a minimum amount of work being done. In other words, if anything is designed, it should be designed so that it will work for years. It should not be designed to hold up for six months or a year and then go to pieces. For example, some sewage treatment plant operators have a lot of trouble with the electrical work. I wonder if we could have better specifications on electrical work in the treatment plants? Generally speaking, in the

smaller towns the electricians are not too competent in doing industrial work of this sort. Probably the engineer should give more suggestive specifications on the electrical work.

Joe Raye, Superintendent of Sewage Treatment, Clearwater, Fla.:—Most of the problems have been covered. Personally, I divide troubles into three phases—engineering, mechanical and operational. In the engineering field it is the problem of over-design. This is serious, especially in an area where it is anyone's guess what the population will be next year. The state board of health has laid down rules and regulations regarding the building of treatment plants and lift stations, and the pumps to handle the sewage. Sometimes the areas do not develop as fast as expected. The operators then wind up with a lot of problems. Retention time in the wet well may be as long as 3 or 4 hr. As a result, wet wells and lift stations cease to be satisfactory, and there is not much the operator can do. Sometimes it is possible to put in divider walls and cut down the volume. In areas that are developing it might be feasible to design the wet wells to use only a part of the capacity until the flow approaches design flow. Certainly a small pump could be used to start with and the size increased later.

Mr. Greenleaf:—The preceding comments bring to mind more strongly than ever the fact that to properly design any engineering structure the engineer must listen with a great deal of care to the problems of the operators. Unless he is cognizant of the problems of the operators, it will be accidental if a good design does resolve. The problems that have been spoken of are problems that everyone has in design.

Manual of Practice No. 3 of the Federation, "Occupational Hazards in the Operation of Sewage Works," is available and I recommend that everybody who is likely to be around a lift station, particularly the wet well, read the manual before sticking their head down in the wet well because they might not pull it out. The number one safety regulation is: Do not go in a wet well by yourself. Have someone available with a rope tied around you to pull you out if necessary. There is no use going down after someone; you are just adding more weight to the load somebody else has to pull out, unless you go in with safety equipment.

Check over the safety equipment; be sure that it works. One thing for example, although it has nothing particular to do with lift stations, is gas masks for chlorine. The canister has a date when it was checked last and also there is an expiration date. Better check up and see what condition your mask is in. Do not go down in the lift station wet well with a chlorine gas mask, it will not give one bit of oxygen.

Someone mentioned that the wet well bottom was too flat. What degree of slope is needed?

Bob Simon, Superintendent of Sewage Treatment, Orlando, Fla.:—My experience has been about 60°. My personal idea is that the lowest part of the wet well should be above the pump bowl and in the bottom of the wet well should be the piping into the pump.

John W. Wakefield, Sanitary Engineer, Florida State Board of Health, Jacksonville, Fla.:—This is purely an exploratory question: what would happen if air was put in the lift station wet well? This matter came up in connection with a septic tank lift station. We didn't know, but thought that maybe air in this lift station might reduce the odor a little bit. An air compressor was connected in series with the pump so that the compressor would cut off before the pump came on. I'm not sure this is the right answer. One thing, it would keep the sewage agitated so that solids

would not settle in the wet well. Also the air would keep the sewage fresh.

Charles Richheimer, Consulting Engineer, Reynolds, Smith and Hills, Jacksonville, Fla.:—Unless you have some method of washing down the wet well or getting the solids out, they will settle on the flattest slope of the wet well. However, there are other ways to accomplish the same result. A flat slope in a wet well will not present problems if it is kept washed down. Generally, there is a water line around lift stations that is used to keep the float well clear, or the electrodes free from scum. Use that same idea and run a pipe around the inside high on the wet well wall and let the water constantly flow. There is no one answer to any of these problems. What will work well at one installation, or will be economically justifiable is not always economical to put in at another situation.

Wilson Calaway, Assistant Professor of Sanitary Science, University of Florida, Gainesville, Fla.:—I can safely make the statement that if there are any holes around and if sewage or water run into them, eventually they will have to be dragged out for repairs. When it is necessary to use a sponge to get the last drop of water out it is a poor design. I have a distinct dislike for bell type suctions that hang over into a pot hole, because they always leave a little water.

Even a 90° slope on a wet well, if it were possible, might collect a considerable amount of solids. A neat cement coat troweled down will help a lot in getting the solids to move along. If there are some little solids hung up it will be hard to move them. A good inspection on the finish on the sloped bottom will be quite a help.

Hardy Croom, Engineer, National Container Corp., Valdosta, Ga.:—It has been observed that the sewage flowing through a hopper bottom tries to conform to a cone. Why not design the wet well bottom in the shape of a cone and let the water, swirling as it goes toward the pump suction, wash out this sludge along with the sewage?

Mr. Wakefield:—This is a case where the design problem requires some middle ground. The problem of providing the wet well with a 60° slope will be one of construction. The idea of the circular hopper with swirling motion of the water is good. It has been tried. There have been a number of lift stations designed like that, but here again a problem is created when appreciable velocities produce a vortex at the pump suction.

There also is the problem of additional construction cost when the wet well slope is increased. In addition, there is always a limit on the amount of money that can be spent. Some of the things that are the result of design do create problems of maintenance. However, it still is sound design to try a middle-ground approach between what is the least expensive and what is the best from the operating point of view.

Grit Chambers

Chairman Seager:—Grit chambers are something that interest almost all sewage treatment plant operators.

Walter J. Parks, Consulting Engineer, Jacksonville, Fla.:—The problem of grit removal in general from sanitary sewage is perhaps the most unsolved problem that designers and operators have to cope with today. I think the clarifiers, high-rate and standard-rate trickling filters, activated sludge, secondary clarifiers and other features of the average complete sewage treatment plant are functioning basically as designed and with a certain degree of satisfaction. But grit removal is a problem.

A large part of my practice is confined to clients who are very dollar conscious. They are spending their own money for the required sewage treatment facilities. What they build they have to pay for now. Conse-

quently, the design engineer must be conscious of costs to stay in business, and that is good. The value of the dollar has a lot to do with grit removal. In the many small plants that are being built in Florida today there are perhaps as many dollars being spent as there are for large municipal plants.

Many practical problems of design have to be reckoned and coped with that do not necessarily apply to the larger municipal facilities. For instance in designing, effort is made not to pump until the gravity sewers are at what is considered to be the lowest economic depth. When this point is reached in the judgment of the designer, it is necessary to pump. Pumping may be at the plant or some outlying point on the sewage collection system.

The question immediately arises as to whether or not the grit will be removed at the lift station or elsewhere. On these small plants with small lift stations, when the sewer comes into the lift station at an elevation of 8 to 10 ft. below the ground surface it is difficult to design and construct grit removal facilities. The operator who tries to operate them later will think they are even worse than the designer thought they were when he put them on the drawing board and incorporated them in the plans. As has been mentioned earlier, it is easy to draw something on the drawing board and it is something else to build it. It is also another matter to operate it.

I have, perhaps, been accused justly of leaving grit removal facilities out of as many small plants as any designer in Florida. I fight it off as long as possible simply because it is unreasonable to spend, for instance, $8,000 for grit removal facilities on a sewage treatment plant that will not cost more than $30,000. The ideal situation would be to have facilities that are so economical in cost that they could be applied to any plant and would work with ease and efficiency. Such a facility is not available, yet. Consequently, I personally try to avoid the provision of grit removal facilities on small plants, knowing that ultimately there will be problems with grit which will justify removal. Perhaps it would be better to plan on shutting down the small sewage treatment plant every four or five years and taking out the sand and grit than to provide these facilities initially.

Now, when the design engineer gets into the design of treatment plants of the size and capacity that warrant the cost of grit removal facilities, and the size is such that the facilities can be built with convenience, then he is faced with the decision on what means of grit removal shall be used. Even then it is necessary to be dollar conscious.

One of the best solutions to the problem, although far from the final answer, is the use of grit removal channels. The formula for the channel design is simply a derivation of the old basic hydraulic formula that Q is equal to AV. It has worked with a reasonable degree of success.

The problem of grit removal involves trying to separate the inorganic solids that are being transported by the water from the organic solids in the raw sewage. The best approach is to remove as much grit and as little organic material as possible. Once this is accomplished the next question is how long can the grit remain in some confined space within a flow channel or elsewhere before it is removed? There are putrescible organic solids mixed with the inorganic material.

The removal of the grit after separation presents problems. Small treatment plants still must be considered from the dollars and cents standpoint. The operator and his assistants will have a hand job of periodically shoveling the grit out of the collection

channel and getting rid of it. When the physical and monetary magnitude of the project will permit there are numerous mechanisms, devices and procedures that can be used with a reasonable degree of satisfaction. My inclination in design is to employ simple mechanical removal by scrappers, screw conveyors or otherwise. The problem of grit removal requires removing grit without organic solids and getting rid of the grit as fast as possible.

Chairman Seager:—The lack of a grit chamber at the sewage treatment plant in Winter Haven did not cause any trouble. I cannot say that it will not happen in the future, but the plant has been satisfactorily operated almost five years.

Mr. William C. Tims, Superintendent, Sewage Treatment Plant, Tampa, Fla.†*:*—There are various grit channels or grit chambers and grit mechanisms. At the Tampa Sewage Treatment Plant there was no grit. A sieve test showed that 5 per cent of the inorganic material remained on the No. 200 sieve, 45 per cent remained on the No. 100 sieve. It was silt, not sand and was very difficult to handle. The mechanism clogged up all the time. But we did remedy the situation, and the channel is now working successfully. After some overhauling it is possible now to obtain a fair amount of grit removal with the mechanism. Every other bucket was removed and spreaders put in to take some of the load from the shear pins. The buckets are large, holding 2.7 cu. ft. and that is a load when a large amount of organic material is moved along.

Velocity flow through the channels was not adequate. It had dropped to .3 to .5 ft. per sec. resulting in sedimentation. To alleviate this condition and make the mechanism work, longitudinal pipes were installed the full length of the grit channel. These pipes were drilled with 1-in. orifices on 4-ft. centers; then a small compressor was hooked to the line. It proved so successful that a 260 c.f.m. blower was purchased and installed. The blower was moved closer to the header line and larger header and feeder pipes were used. The air lines were laid 18 in. above the floor of the channel to clear the bucket and 16 in. out from the side wall of the channel. These channels have walls sloping to the channel bottom. The use of air proved exceptionally successful. Here is a five-month comparison on the effectiveness of the air:

Month	Grit Removal (cu. ft.)	
	1953	1954
Feb.	43.98	166.8
Mar.	37.01	152.9
Apr.	14.09	192.9
May	16.12	220.3
June	25.85	236.6

Mr. Wakefield:—I still believe that 99.99 per cent of the sewer systems in Florida will have grit in them, and will give trouble. Sooner-or-later someone will want to put a grit chamber in almost any size treatment plant. It will be a sad commentary on the sanitary engineering profession if it can not figure a cheap way to get grit out of the sewage. It is something that needs a lot of thought and some research.

David B. Smith, Professor of Civil Engineering, University of Florida, Gainesville, Fla.:—Back in the early part of 1946, I went to the University of Florida to obtain some field data involving a new treatment plant. In probing around the old Imhoff tank it was surprising to find practically no grit accumulated in the bottom. The conclusion was that the collection system was pretty tight and grit was not getting into the sewers. The new

† Presently, Superintendent of Utilities, Carol City Utilities Company, Miami, Fla.

treatment plant was designed without the grit chamber, but hydraulic provisions were made for one if it became necessary at a later date. Since then it has been necessary to take the digester out of operation and remove the grit because the tank was becoming inoperative. The effective capacity of the digester had been greatly reduced. The University is planning to construct the grit chamber, something that probably should have been done to begin with, because it was known that a large expansion was coming. This is the sort of thing that was just pointed out. I believe there is not a system in the state that is free from grit.

PERSONAL LIABILITY OF PUBLIC EMPLOYEES ENGAGED IN GOVERNMENTAL FUNCTIONS *

By John R. Nimocks

Deputy City Attorney, Long Beach, Calif.

The rule that "the king can do no wrong" arose in the days of the absolute monarch, answerable to no one except his own conscience and his God. This concept became a part of the common law of England, was brought to this country by the early settlers and has always been a part of our American system of law. It was translated in this country into "the government can do no wrong" and is commonly spoken of as governmental immunity from suit or, more accurately, from liability for torts or civil wrongs committed in its name or by its employees. In recent years, the immunity has been whittled down by various statutory enactments in which the legislature or Congress has specified certain fields in which the government, in effect, waives its immunity and says "we will be responsible, if you fit the terms of the statute."

The law has always made a distinction in the liability of a government when it is acting as a government and its liability when it is acting in a proprietary capacity or, more simply, when it is engaged in a business enterprise. It has always been the case that when acting in a business enterprise, a government is liable, just as any other business is liable. Examples of such activity are the water department, gas department, harbor department, municipal auditorium and stadium, municipal airport, electric utility and other similar activities of many municipalities. In general, all are business or proprietary activities.

Immunity applies to the city when it is doing something in the furtherance of public health, morals, safety or welfare. Typical examples of these activities are police and fire departments, building inspection, health departments, street work, parks and playgrounds, and last, but by no means least, the sewage disposal departments through their direct connection with the public health.

Public Employee Liability

How does this personally affect the public employee? First, it should be said that *any* employee who negligently or intentionally, for that matter, injures another person or his property is personally responsible for the damage he causes; this whether or not he works for the city in its proprietary capacity or in its governmental capacity. As an employee, he

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is the agent of the city. As pointed out, the city, if acting in its proprietary capacity, is also responsible. Cities have found it wise to insure against such liability. Most find it no more expensive to include the employee in the coverage and thus the employee is protected.

Other cities are primarily self-insured. They simply budget each year an amount to be spent for this purpose. Although exact information is not available, the impression is that they save considerable sums over having these matters handled by an insurance carrier. Some city councils have decided, as a matter of policy, that since the city is self-insured and since ordinary insurance would cover the employee also, no attempt will be made to collect from or require that the employee reimburse the city. Reimbursement is the legal right of the city if it wishes to enforce it. Such a policy could be changed at any time, although there is no reason to believe that there is any intention of doing so. There have been, from time to time, certain indications that reimbursement might be required from an employee who was grossly and inexcusably negligent. It also is possible that disciplinary action could be imposed. It is fairly common to demote a truck driver back to a laborer classification simply because the man is accident prone or a poor driver and does so much property damage that he costs the city money.

Governmental Liability

When the city does insure, either by actual insurance or through the self-insurance route, what is insured against is the liability of the city and, incidentally, that of the employee. The employee in the "governmental" field is faced with the situation where the city is not liable because immune, but the employee is personally responsible because it was his personal negligence that caused damage.

California Experiences

Generally speaking, cities can pay public funds only for public purposes and upon obligations that can be legally enforced against it. Public officials deal with "trust" funds for the public. If illegal expenditures are made the men or body who authorized such illegal expenditures may find themselves personally liable for the amounts paid out. An example is the decision of the California Supreme Court in *Mines* v. *Del Valle*, 201 Cal. 273, in which members of the Los Angeles Board of Public Service Commission were held liable to repay $12,000 expended in advertising for and urging the adoption of a bond issue at an election for that purpose. The bonds were to have been used in extending the electric system. Expenditures of this type were held by the court to be illegal.

In the case of *Osburn* v. *Stone*, 170 Cal. 480, the court held that if illegal contracts are entered into without competitive bidding or with a public official who has a prohibited interest in the contract, the amounts paid out may be recovered from the mayor and councilmen who authorized the contracts.

There are many court decisions defining and setting forth illegal expenditures of funds. Most decisions do not involve trying to hold the individuals responsible, although many are criminal proceedings against the individuals. In *People* v. *Harby*, 51 Cal. App. 2d. 759, a Los Angeles councilman was convicted of using a city car to take a vacation trip to Montana; in *People* v. *Johnson*, 14 Cal. App. 2d. 373, a San Diego County assessor was convicted for making a refund of money, collected by him as taxes, to one who he thought had a proper refund claim; and in *People* v. *Dillon*, 199 Cal. 1, convicting a finance officer and purchasing agent of Fresno who, through his office, bought personal things for himself and his

friends, city funds being used in making the purchase, and the individuals reimbursing the city. The courts further hold that the good faith of the individual or lack of fraudulent intent are not defenses; the illegal expenditure is what is prohibited.

These points are emphasized to make it clear that even though an employee may feel that the city ought to furnish protection the city is in an extremely precarious position in trying to do so, unless it has first taken the necessary legal enabling steps. The councilman who votes to pay the claim or judgment arising out of the activities of an employee may well find himself paying the cost out of his own pocket and possibly subjecting himself to criminal charges as well.

The City Attorney

Consider for a moment the situation of the attorney whose job it is to give legal advice to the councilman. The denial of such a claim is not recommended out of caprice or whimsy but for the real reasons mentioned. The councilman who found himself personally liable for following the advice of the attorney to pay such a claim would certainly not be sympathetic to the excuse that it was given for the purpose of assisting the employee. Additionally, whether the reader is aware of it or not, lawyers are responsible for their negligence in wrongly advising their clients. There certainly would be no excuse in the situation where, knowing better, erroneous advice was given intentionally.

To sum up the situation, the employee is protected if he is engaged in an activity wherein the city is also liable. If the city is not legally liable, the employee is not protected.

The Vehicle Code

Some statutes make the city liable where it would not otherwise be. The California Vehicle Code provides for the responsibility of the city just as any other person or corporation is liable. Even then there are certain special rules available. For instance, police or fire equipment, if operated with siren and red lights and on an emergency call, are exempt from obeying traffic regulations so long as they do not arbitrarily exercise the privilege.

Another rule states that the provisions of the Vehicle Code do not apply to public employees or motor vehicles "while actually engaged in work upon the surface of the highway." A recent decision of the Appellate Department of the California Superior Court has held that a street sweeper comes within that classification. Neither the employee nor the city is liable, even though if it had been a truck or other vehicle not working on the surface the liability would be clear.

Property Damage

Since 1923, cities have been responsible for dangerous or defective conditions of public property. In this field, the courts have expanded liability of cities by expanding the concept of what is a dangerous or defective condition of public property. At the same time, this is the field where there is the least likelihood of an individual employee being involved. Typical examples are the crack, raise or hole in the sidewalk or the hole in the parkway. Governmental liability has been applied to what the courts call "design or plan of operation," such as failure to separate playground areas for small children from baseball diamonds, the claimant being struck by a batted ball; incinerators on a school ground; burning dumps from which fire spread; bad design of a street, making a dangerous condition; painting a street center line up to an obstruction so that a person following the line on a foggy night collided with the obstruction. It is also possible

to have a faulty design in sewer or storm drain systems that will make the city responsible.

Primary concern of public employees is with the things occurring in day-to-day operations. For example, the manhole cover left off, so that falls, or which is improperly fitted or replaced so that it trips a person; the residence flooded by a stoppage due to sewer cleaning operations. These are typical of the situations where the city cannot legally pay because they are not classified as dangerous or defective conditions of public property for which the city has responsibility. In addition, there is a requirement of the Public Liability Act, which states that a responsible official of the city must have knowledge or notice of the condition and a reasonable time to make repairs.

All of these principles occasionally lead to situations that appear ridiculous unless the reasons involved are understood. To illustrate, a trenching machine strikes a pipe line or telephone cable. If a water or a gas line is being laid, the city pays. However, if a sewer line is being laid, the city does not pay. Why? Simply because in the case of the water and gas lines the city is acting in its proprietary capacity and is responsible for negligence. When laying the sewer line, the city acts as a government and is not liable for negligence.

A post hole is dug to erect a street barricade. In doing so an overhead cable of the telephone company is struck breaking a couple of poles. If the cable is struck while digging the hole, the city does not pay because it is acting as a government in making a street repair. On the other hand if the digger is left up as the vehicle is moved and causes the damage the city pays because it arises out of the operation of a motor vehicle for which the city is responsible by statute, regardless of governmental or proprietary capacity.

Public Employee Protection

The public employee is not left entirely without protection. California Government Code Section 1981 provides that whenever a third person claims a pubic employee negligently injured him or his property, such person must file with the employee a sworn statement of his claim within 90 days after the occurrence or he is barred from recovery. However, if such a claim is served, the claimant is free to proceed as he sees fit.

Means of Protection

What are the possibilities of protection? Several avenues appear available.

1. A possible approach is the enactment of state legislation which would make the city responsible for acts of its employees like a private corporation. This approach would undoubtedly run into the opposition of all the municipalities of the state. Obviously, the cities will not willingly undertake this additional responsibility which will greatly enlarge their liabilities. The League of California Cities has fought every attempt to enlarge upon Municipal Tort Liability and will undoubtedly continue to do so.

2. The public employee can insure himself against this risk at his own expense and in amounts he deems necessary.

3. The employees can obtain protection from the city. This is the one that appears to be the best. It may be that many employees have already been protected. The available information is that most cities carrying insurance do not cover the personal responsibility of the employee, but only that of the city. The city attorney of Berkeley, Calif. has made several presentations to the attorneys' section of the League of California Cities indicating this to be the result of his surveys of general municipal practice.

Governmental Insurance

In 1943, the California Legislature amended Government Code Section 1956 to provide, that cities and other governmental agencies could properly insure their officers and employees against liability for "injuries or damages resulting from their negligence or carelessness during the course of their service or employment . . . ," and other coverages for employee responsibility arising out of dangerous or defective conditions. The author is not aware of any case raising the question of whether or not the section is properly applicable to a chartered city. There is no reason to believe that a court would not hold it applicable. The city attorney of Berkeley indicated, in 1952, that the city had for several years made its insurance coverage provide ". . . the coverage afforded by this policy shall . . . insure the officers and employees. . . against any liability for injuries . . . resulting from their negligence or carelessness . . . including claims for damages or injuries for false arrest, false imprisonment, malicious prosecution and other similar actions." Without study of the matter it would appear that the city might be on shaky ground if an attempt was made to justify expenditure for false arrest insurance on the basis of the cited statute.

California Government Code Section 1956 permits self-insurance for the employee coverages permitted. Attempts to work out such a program are not known, but it should be possible, since it is expressly authorized. One approach that has appeal would be to have the protection set forth in the salary ordinance the city annually adopts, providing for the furnishing of coverage either by regular insurance or self-insurance. This would have the effect of making the agreement to furnish coverage a part of the salary or wage contract between the city and the individual employee. Presumably, under this approach, false arrest or other types of coverage could be furnished legitimately.

Concerted Action

The importance of the problem to public employees cannot be overemphasized since it may involve their own personal financial situation. It is suggested to those affected that a concerted approach by all the employees of a particular city who operate in a governmental function would probably meet with more success than sporadic or individual attempts by a department or division. Some of the employees so engaged include firemen, policemen, parks and playgrounds employees, street workers, lawyers, engineers, tree trimmers, hospital workers, garbage and trash collection and disposal workers, lifeguards and others. Not all groups will have the same interest in this protection because their dealing with the public may be slight or in a way that does not involve much risk of doing damage to others. It might be an excellent part of the activities of the city employees association.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"Take time to think—it is a source of power."—*Anon.*

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

Annual Report of the Detroit, Mich., Sewage Treatment Plant for the Two Fiscal Years, 1953 and 1954 *

General

The total pumpage of sewage from the Detroit metropolitan area was treated by primary sedimentation and chlorination. Solids were handled by vacuum filtration or digestion. The single digester handled one-fourth of the sludge, serving primarily as a source of digester gas for heating purposes.

Pumpage amounted to 150,020 m.g. in 1953 and 162,060 m.g. in 1954 reflecting a continued increase in the flow. The 1954 flow was the greatest yearly total experienced and is particularly significant considering that two pumping stations were out of operation for varying periods of time and that the rainfall has decreased for the second straight year. The 1953 flow, while less than for 1952 (153,980 m.g.), is also significant when consideration is given to the inoperation of the 140 m.g.d. pumping station for 69.5 days; decreased rainfall and the elimination of river water from the interceptor (by raising crest of regulator dams). The highest single day's sewage pumpage was a record 744.72 m.g. on Feb. 16, 1954. The survey of the Detroit and lower Rouge Rivers was continued on a weekly sampling basis as in previous years. Other survey and inspection trips aided in maintaining a check on river and lake conditions.

Cleaning of the incinerator ash lagoon was undertaken during the summer on a contract basis. Air-dried digester sludge resulting from the annual cleaning of the digester was given to individuals who would haul it away. During the past two years 137 cu. yds. have been removed.

The regulators controlling the flow of trunk sewers into the interceptors were inspected regularly to make certain all sanitary flow was diverted to the interceptors and river water was excluded. At times of peak flow caused by the increased use of water for air conditioning, the regulators were close to diverting sewage to the river and were adjusted for a higher hydraulic gradient in the interceptor. The plant by-pass was not used at any time.

A restriction in the outfall conduit and diffuser resulted in an abnormal elevation in the sedimentation tank collecting channel. Investigation disclosed that the diffuser cap located in 40 ft. of water had been forced into the 90° elbow of the conduit causing a restriction of the flow. The diffuser will be removed and stored.

Solids Removal

Mechanical grit collectors and incineration have satisfactorily handled the grit. Complete overhauling was made in 1954. The presence of raw garbage, paper and tin cans at the bar rack, was evident in the fall of 1953 indi-

* For last previous extract see THIS JOURNAL, **26**, 4, 564 (April, 1954).

cating the introduction of raw garbage into the sewers. This marked the start of a trend toward poorer solids recovery in the sedimentation tanks, higher chemical dosage for sludge conditioning, and unground garbage on the vacuum filters.

During periods of heavy storm flow when leaves are recovered at a faster rate than can be ground they are stored temporarily on the floor of the grit building.

The practice of stopping the sedimentation tank main collectors during and after heavy storm flows, to relieve the overloading of the cross collectors and control the high peaks in sludge concentration, was continued with good results in minimizing cross collector stalling.

The removal of grease and scum increased to a new high of 2,646 tons. Difficulties in pumping sticks and debris have been greatly reduced by installing larger capacity (200 g.p.m.) pumps of the screwpeller type.

Digestion

Following the annual cleaning of the digester in July, 1953, the composition roof of the floating cover was replaced. The digester feeding rate was periodically increased to a maximum of 45 tons of solids per day (dry basis). Oil and scum reached a maximum depth of 7 ft. and were controlled by several heavy, rapid draw-offs above the scum line.

The system for odorizing digester gas proved valuable in locating gas leaks. Its effectiveness was demonstrated when the underground high pressure gas line broke outside the boiler room. The odor was readily detected and the break repaired before a dangerous condition developed.

Sludge Filtration

Although the total tons of sludge solids filtered in 1953 increased by 15 per cent, there was a decrease the following year from 56,962 tons to 54,818 tons. This may be a reflection of poorer solids removal.

The use of ferrous sulphate, a waste by-product of the steel industry, was discontinued in 1953 when the original supplier experienced difficulty in handling and storing the liquor. Filtering requirements favored the use of ferric chloride and the use of this conditioning agent was greatly increased in 1954. Sludge characteristics required a greater quantity of iron salts for coagulation.

Waste slurry from acetylene manufacture continued as the main source of lime. When filtration is possible with lime only, it is the practice to clean the filters by conditioning with ferric chloride for 4 hr. on alternate days.

A nylon filter cloth was placed in normal service producing a high yield. However, the cloth "blinded" after 200 hr. of service, requiring periodic cleanings with muriatic acid. The cloth was still in excellent condition at the end of 1,135 hr. of service. Testing will continue and final results evaluated at a later date.

Sludge Incineration

Efforts were concentrated, during 1954, on reducing the incinerator fly ash to conform to the subject code. A third incinerator was used reducing the tonnage per unit, the operating temperatures and the gas velocities.

To maintain combustion temperatures during periods of low filter cake production, fuel oil was required at the rate of .125 gal. per ton (wet basis). This is an increase of .111 gal. per ton over the previous year but was justified in that complaints of fly-ash were reduced to a minimum.

Chlorination

Chlorination continued on the same basis as in previous years. During the warm weather months chlorine was applied at 100 per cent of demand, reducing to 60 per cent in the winter.

TABLE I.—Summary of Operating Data at Detroit, Mich., for the Fiscal Years, 1953 and 1954.

Item	Average 1953	1954
Rainfall, total (in.)	29	25.4
Estimated connected pop.	2,700,000	2,700,000
Sewage pumped (m.g.d.)	411	444
Solids removed:		
Grit, dry (tons)	8,377	9,186
Tank scum (tons):		
Dry	1,462	1,603
Volatile	1,317	1,444
Susp. solids (tons):		
Dry	71,359	59,545
Volatile	43,329	38,433
Total solids (tons):		
Dry	81,198	70,334
Volatile	47,797	43,148
Analytical data:		
Susp. solids:		
Influent (p.p.m.)	220.3	202.3
Effluent (p.p.m.)	106	116
Reduction (%)	51.9	42.7
B.O.D.:		
Influent (p.p.m.)	147.3	151.8
Effluent (p.p.m.)	89.8	95.6
Reduction (%)	39	36.9
Grit (%):		
Solids	45.7	50.6
Volatile	44.5	35
Raw sludge to digester (%):		
Total solids	10.3	9.9
Volatile solids	57.9	61
Sludge digestion:		
Total added (m.g.)	28.4	27.3
Dry solids added (tons)	12,151.2	11,369
Dry solids withdrawn (tons)	9,510.5	7,747 †
Supernatant (%):		
Solids	7.9	6.9
Volatile solids	46.8	49.6
Gas production:		
1,000 cu. ft.	95,650.6	85,880.4
Cu. ft. per vol. sol. added	6.7	6.3
Sludge filtered:		
Total (m.g.)	122.9	121.3
Dry solids (tons)	57	54.8
Solids (%)	10.7	10.8
Volatile solids (%)	57.0	58.2
Filter yield (lb./sq. ft./hr.) ‡	3.5–4	3.9
Sludge cake, filtered (%):		
Solids	35.5	36.1
Volatile	53.6	54.4
Incineration:		
Wet (tons)	201,803	191,243
Dry (tons)	74,623	73,390
Wet feed rate (tons/hr./incin.)	11.5	8.5
Fuel oil per wet ton burned (gal.)	0.014	0.125
Chlorination (p.p.m.):		
Demand	6.03	4.64
Applied	4.05	3.67

† Includes 220.1 tons of scum.
‡ Depending on conditioning chemicals used.

TABLE II.—Summary of Operating Expenses, Detroit, Mich., 1953 and 1954.

Item	Fiscal Year Ended June 30 1954	1953
General plant	$ 177,354.05	$ 163,441.36
Pumping stations	243,689.95	236,276.36
Bar rack and grit removal	71,801.34	42,127.28
Sedimentation	84,344.26	71,045.43
Chlorination	201,276.48	193,788.77
Digestion	9,821.81	1,322.95
Filtration and chemicals	194,142.78	154,485.32
Incineration and ash handling	361,124.05	320,321.21
Boiler plant	53,374.72	50,976.55
Dearborn sewage treatment	149,817.99	147,167.00
Interceptors	19,476.32	6,415.49
Sanitary sewage pump station	270,000.00	263,000.00
Miscellaneous	89,388.64	79,673.77
Administration	96,093.12	87,783.60
Depreciation	511,127.00	511,495.00
Total	$2,532,832.51	$2,326,674.19

Fall and spring chlorination was at 80 per cent of demand.

Following numerous tests the point for determining chlorine demands was changed in July, 1953 from the sedimentation tank influent to the effluent. Partly as a result of this change the average chlorine demand (on which chlorinator settings are based) dropped from 6.03 p.p.m. the previous year to 4.64 p.p.m. This is the lowest yearly value since operations began. Sewage volume increased 8 per cent and the amount of chlorine required showed a slight decrease; moreover, it was far more effective in reducing bacterial numbers. Even with partial chlorination 97 per cent of the *B. Coli* were eliminated.

Control and Research

The laboratory is responsible for all operations in connection with chlorination control and the testing of materials. Cyanide samples were checked and as a result of follow-up work in checking cyanide sources, the number of "slugs" of this material discharged to the sewers was less than the previous year.

A new investigation was undertaken to correlate analytical properties of sewage sludge with its conditioning chemical demand.

Experiments on sludge filtration, incinerator fly-ash recovery, and scum incineration were carried on during 1953. Satisfactory results were obtained in burning grease and scum on the lower hearths of an incinerator. Grease is pumped automatically from the grease separator for 3 to 10 sec. at intervals of 3 to 6 min. The grease is ignited by the hot ash and there are no deleterious effects on incinerator operation.

Civil Defense

The practice of conducting large groups of visitors through the treatment facilities was discouraged as a security measure. Several small groups of college students and organized societies were granted conducted tours. An air raid defense program instituted in 1951 was kept in readiness.

In the fall of 1954 work clothing was provided for all operating and maintenance personnel who came in close contact with sewage or sewage solids. Approximately 140 employees are supplied with a weekly change of clean work clothes.

Table I summarizes the 1952–53 and 1953–54 operation data. Table II summarizes the operating expenses for this same period.

THE USE OF MANUAL OF PRACTICE NO. 3

In September, 1949, six years ago this month, Federation Manual of Practice No. 3, "Municipal Sewer Ordinance," was published. In the ensuing years nearly 3,000 copies have been sold to city managers, city attorneys, consulting engineers and high-ranking municipal officials. Copies have gone to every state in the Union, to Canada, Hawaii and other areas where modern sewage facilities require modern ordinances to assure fair and efficient operation.

To obtain some idea on the use of the manual the state and territorial sanitary engineers were requested late in 1954 to furnish comments on their knowledge of the use of the manual. Response was most gratifying with replies being received from 34 states and territories together with several volunteer comments engendered by an appeal in this Journal, September, 1954.

Although less than a dozen states reported "no knowledge" of the specific use of the manual for new, revised, or proposed ordinances the general response can be summed up by the comment from Georgia "It has been our practice to promote the manual and to recommend its use at every available opportunity. However, our knowledge as to who has actually used the manual and to what extent is very meager."

Several states apparently were in close detailed touch with the use of the manual through the activities of their field engineers. The reply from the Ohio Department of Health commented "Since 1951 some 21 cities (population over 5,000) and 30 vil-

TABLE I.—Use of the Municipal Sewer Ordinance Manual by Municipalities*

State or Territory[1]	Number of Municipalities Using Manual in Development of			Comment
	New Ordinance	Revised Ordinance	Proposed Ordinance	
Arizona	—	—	4	
Arkansas	1	1	3	
Connecticut	6	—	4	
Delaware	1	—	—	
Georgia	5	—	—	
Hawaii	—	2	—	Counties
Idaho	1	—	1	
Indiana	6	—	4	
Iowa	1	—	—	
Kansas	7	2	—	25 to 50 other possibilities
Louisiana	1	—	—	
Mississippi	1	—	1	
Missouri	1	2	1	
Nevada	—	—	2	
North Carolina	3	—	1	
Ohio	√	√	—	51 cities and villages
Oregon	—	—	1	
South Dakota	7	6	2	
Tennessee	1	—	2	
Texas	—	1	—	Reference use
Wisconsin	—	1	—	Widely used as reference

* Data obtained from questionnaire sent to all state sanitary engineers from Federation headquarters, November 30, 1954.

[1] Replies and comments also were received from Ala., Maine, Md., Mass., Minn., Mont., N. Dakota, New Mexico, N. Y., Pa., R. I., Utah and W. Va.

lages have enacted new ordinances or revised old ordinances on municipal sewers. We are certain that the consultants or officials responsible for the ordinances have used the manual quite extensively in preparation of the ordinances. It is our opinion that the numbers reported are on the conservative side although definite statements cannot be made from the information available." Kansas, also, reported a wide use of the manual "—there are at least 25 and possibly 50 communities which have made use of the manual, either as a guide for general information on sewers, or for use in adopting an ordinance."

The use of the manual is not limited to sewage and industrial wastes people. In support of this is the comment from the Minnesota Department of Health, "The development of ordinances for sewers for municipalities is largely handled by the staff of the League of Municipalities (Minnesota) in cooperation with local authorities. The legal advisor advises us that because of the small population in the municipalities the manual has been used largely for reference purposes."

Based on the comments of the state sanitary engineers the manual has been widely used as a reference work in preparing and revising municipal and industrial waste sewer ordinances. Tabulation of the replies (Table I) indicates 126 specific instances of recorded use by municipalities. The heavy use of the manual in the development of new ordinances is in keeping with the tremendous increase in the construction of sewage treatment facilities during this period.

The Division of Sanitary Engineering, West Virginia Department of Health made apt use of the manual—"In 1949 we purchased 100 copies of the Ordinance and mailed a copy to all the larger communities in the state. We also furnished copies to the consulting engineers practicing in West Virginia."

There will be a considerable use made of the ordinance in the future as cities continue to engage in extensive sewerage construction programs. This will be particularly true as municipal officials recognize that their treatment facilities are valuable and important properties.

The names of the municipalities using the manual are available from the headquarters office of the Federation.

RESTAURANT GREASE INTERCEPTOR *

One answer to the interception of grease from restaurants not served by a sanitary sewer system is presented in Figure 1. This low pressure grease interceptor is the result of efforts by the engineering and building department of the Howard Johnson restaurant organization to develop a method of low cost effective grease removal.

Grease is skimmed from the 150-gal. grease trap by means of a skimmer pipe. Skimming action is obtained by creating a vacuum in the 66-gal. low pressure tank connected to the skimmer pipe. This is accomplished by filling the tank with water through a hose connection. When the 1½-in. return pipe is opened the water in the tank discharges to the interceptor and if all other valves are closed a vacuum is created in the tank. Grease can then be drawn into the tank when the skimmer valve is opened.

Solids picked up with the grease settle to the tank bottom and are re-

* Adapted from correspondence received from D. N. Landis, Engineering and Building Dept., Howard Johnson, Inc. of Fla., Miami, Fla.

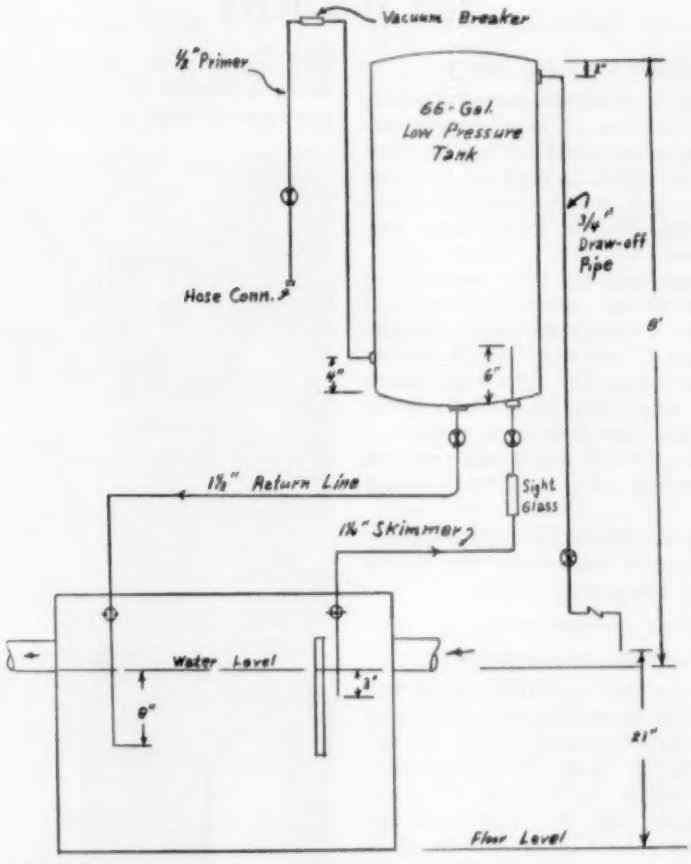


FIGURE 1.—Restaurant grease interceptor using a low pressure tank for grease skimming.

turned to the interceptor. The floating grease is drawn from the tank into containers through the grease removal line when the tank is again filled with water for the next skimming cycle.

Installation costs average approximately $1,000 based on a volume of 10,000 gal. per day. Tests by the Johnson organization indicated grease removal of 500 lb. per month and a relative efficiency of 90 per cent. This installation is reported being used throughout the Dixie Division of the Howard Johnson system where sanitary sewers are not available. Considerable money has been saved in not requiring the pumping of grease traps and the rebuilding of drainfields.

TIPS AND QUIPS

Short Cuts for Sewers

When a headline like the above catches the eye it is not surprising that the mind would be excited. One would be quick to read on in hopes that the text would reveal the secret for better, cheaper, easier, sewer construction.

At last someone has developed a method to lay sewers quickly and cheaply. Perhaps the costly troublesome sewer has been completely revamped. However, the eyes cannot believe what they read. The article announces that short cuts galore are the specialty of a young lady who will teach sewing to "sewers" at a sewing center.

Oh, supernatant and acid sludge to the journalist who dares mix sewers (sū′ĕrs) and sewers (sō′ĕrs).

Packaged Reagents

Reagents are now available in factory-sealed envelopes that provide even the smallest laboratory with a complete handy stock of contaminant-free chemicals. Users of the new packages report that the triple-laminated envelopes proved an effective moisture barrier even after being opened and re-sealed by folding the torn edge twice.

The envelope packed reagents are available from Fisher Scientific Co. under the trade-mark "Gram-Pac." All have 25 grams of Fisher Certified Reagent grade chemicals, except the bulky reagents.

Glassware Distinguisher

Here is a new way to sort Pyrex glass from soft glass and quartz glass in the laboratory. When an assortment of pipettes or other glassware is placed in a jar containing 59 per cent carbon tetrachloride and 41 per cent benzene, the Pyrex glassware becomes invisible, while the soft glass is clearly outlined (Figure 1). This also makes a convenient check for glass tubing.

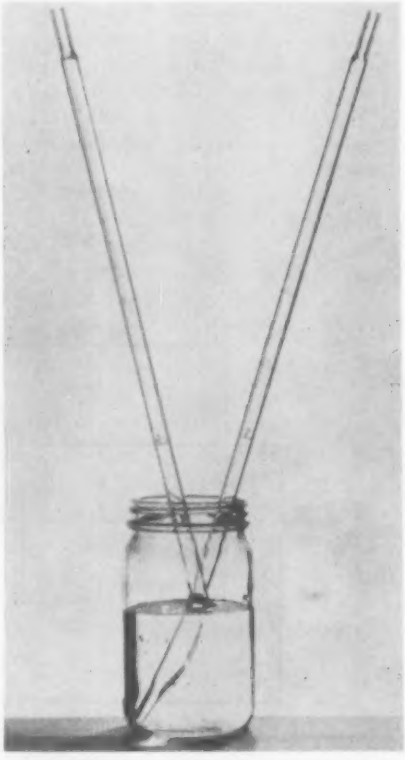


FIGURE 1.—Distinguisher for sorting glassware. Soft glass pipette at right; Pyrex glass pipette at left.

The same effect can be obtained by using reagent-grade tricholorethylene, which can be obtained from laboratory supply houses. Secret of the "distinguisher" is a refractive index almost the same as that of Pyrex glass.

Pennsylvania Clean Streams

Eight more Pennsylvania municipalities were reported in the April 1955 "Clean Streams" issued by the Pennsylvania State Department of Health to have received payment from

state funds representing their 1954 share of the state aid paid to cities in connection with the state clean streams program.

The state aid, passed in 1953, provides annual payments not to exceed two per cent of the cost of construction of the treatment works. These funds are applied on expenses relating to the treatment works. State funds equal to 50 per cent of the cost of plan preparation, based on 1942 costs of construction, also are available to municipalities required to prepare plans for sewage treatment works.

Weed Control

Baron, a nonselective herbicide, is now available for vegetation control. This new chemical, introduced by the Dow Chemical Company, has been given extensive field tests and is reported to be remarkably effective.

Effective through both contact and systemic action, it will kill almost all perennial grasses and herbaceous plants. Baron may be sprayed on the leaves or soil. As a soil sterilant its effectiveness lasts for approximately one season. Animal toxicity is very low. It is easy to use in conventional weed-control spray equipment, presenting no problems of corrosion.

Point-of-Hazard Warnings

Self-sticking accident prevention signs that will stick to irregular surfaces are available from the W. H. Brady Company, 727 W. Glendale Avenue, Milwaukee, Wis.

The signs include both basic purpose (Danger) and specific purpose (No Smoking) signs that can be used alone or in combination. A wide range of messages and colors are available in each of three sizes. Made of impregnated cotton cloth with a temperature-resistant pressure-sensitive adhesive backing, the signs are silicone plastic coated. Each sign is mounted on individual dispenser cards. Peel off and stick!

A definite advantage of these signs is their use to pinpoint vital safety warnings right at the point of hazard. A catalog is available on request.

Stop-Clock Timers

Stop watch accuracy and 4-in. or 8-in. diameter dials combine to produce a timer that is easy to read. This rugged stop clock can take considerable rough handling and its size eliminates the hazard of knocking it off the laboratory table.

Durachrom Stop-clocks featured by Andrew Technical Service, 6972 N. Clark St., Chicago, Ill. are competitively priced with most reliable stop watches.

Microstraining

A process for the purification of industrial water and clarification of paper mill effluents features a patented membrane filter using a finely woven stainless steel filtering media. Openings are as small as 23 microns with as many as 165,000 openings per square inch of fabric. The drum filter provides peripheral filtration radially outwards.

Engineers Needed

California's statewide program of water pollution control continues to create more jobs, and the supply of competent engineers to fill them appears inadequate. Vacancies now exist at Los Angeles and Indio in the south and at Santa Rosa and Bishop in the central part of the state. The recruitment section of the State Personnel Board, 801 Capitol Avenue, Sacramento, Calif., is looking for water pollution control engineers at both the associate and senior level. Interested persons must be prepared to go to California for the interview and examination.

Federation Affairs

TWENTY-EIGHTH ANNUAL MEETING PREVIEW

Ambassador Hotel, Atlantic City, N. J., October 10–13, 1955

★

IN CONJUNCTION WITH

THE NEW JERSEY SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

★

THE OFFICIAL PROGRAM

SUNDAY, OCTOBER 9

Afternoon

Early Registration—Rotunda

Inspection of Exhibits—Lounge, Sun Porch and Venetian Room

MONDAY, OCTOBER 10

Morning

Registration—Rotunda

Inspection of Exhibits—Lounge, Sun Porch and Venetian Room

Twenty-Eighth Annual Meeting Called to Order—Renaissance Room. President David B. Lee

Invocation

Welcome to Atlantic City—Mayor Joseph Altman

Reports of Federation Officers

The Authority Approach to Stream Pollution Control
Robert S. Shaw, Chief, Bureau of Public Health Engineering, New Jersey Department of Health, Trenton, N. J.

Afternoon—Renaissance Room

Westchester County Solves a Sewerage Problem on Long Island Sound
Guy E. Griffin and James M. Brown, Westchester County Department of Public Works, White Plains, N. Y.

Additions to Buffalo Sludge Disposal Facilities
F. W. Crane and G. F. Fynn, Buffalo Sewer Authority, Buffalo, N. Y.; and Charles R. Velzy, Consulting Engineer, New York, N. Y.

Hydraulic Transportation in a Coal-Digested Sludge System
John J. Wirts, Superintendent, Easterly Sewage Treatment Plant, Cleveland, Ohio

Design and Operation of the Wilmington (Delaware) Sewerage System
Roy H. Ritter, Partner, Whitman, Requardt and Associates, Baltimore, Md.

Evening

FAMILY NIGHT ENTERTAINMENT—Renaissance Room

TUESDAY, OCTOBER 11

Morning—Renaissance Room

Natural Sediment, A Factor in Stream Pollution Control
Richard D. Hoak, Senior Fellow, Mellon Institute, Pittsburgh, Pa.

High-Rate Trickling Filters in Germany
Adolf Rumpf, Nassau, Germany

Acid Mine Drainage Problems
W. L. Patrick, Professor of Chemistry, Johns Hopkins University, Baltimore, Md.

Noon

FEDERATION LUNCHEON—Embassy Room
The Federation as an International Force
W. H. Wisely, Executive Secretary, American Society of Civil Engineers, New York, N. Y.

Afternoon—Renaissance Room

Federal Water Pollution Control Legislation
Mark D. Hollis, Chief Engineer, United States Public Health Service, Washington, D. C.

Solving a Large Scale Waste Problem at Appliance Park
K. S. Watson, Consultant, Water Management and Waste Control, General Electric Co., Schenectady, N. Y.; and C. M. Fair, Supervisor, Water and Chemical Wastes Treatment, General Electric Co., Louisville, Ky.

Sewer Maintenance in Los Angeles
Alvin Appel, Superintendent, Sewer Maintenance Division, Department of Public Works, Los Angeles, Calif.

WEDNESDAY, OCTOBER 12

Morning—Renaissance Room

The Use of Radioactive Isotopes in Determining Flow Patterns in Waste Treatment Lagoons
W. C. Seaman, Head, Analytical Research, American Cyanamid Co., Bound Brook, N. J.

Operating Results on Paper Mill Waste Treatment Plants
Harry W. Gehm, Technical Adviser, and Nicholas J. Lardieri, Field Engineer, National Council for Stream Improvement, New York, N. Y.

Petrochemical Waste Treatment Problems
E. B. Showell, Consulting Engineer, Chadds Ford, Pa.; and G. E. Montes, Chief Technologist, National Petrochemical Corp., Tuscola, Ill.

Processing of Phosphorus Furnace Wastes
J. P. Horton, J. D. Malley and H. C. Bays, Development Engineers, Virginia-Carolina Chemical Corp., Richmond, Va.

Afternoon—Renaissance Room

Symposium on Fringe-Area Sanitation
John E. Kiker, Leader, University of Florida
I. Russell Riker, Princeton, N. J.
John W. Wakefield, Florida Department of Health
Myron K. Nelson, Mission, Kansas

Turnpike Sewage Treatment Plants
G. Gale Dixon and H. L. Kaufman, Engineers, Parsons, Brinckerhoff, Hall and MacDonald, New York, N. Y.

Evening

ANNUAL FEDERATION DINNER and DANCE—Renaissance Room

THURSDAY, OCTOBER 13

Morning—Concurrent Sessions

THE OPERATORS' FORUM—Twenty-Two Club
Arthur H. Niles, Leader, Commissioner, Sewage Disposal Division, Toledo, Ohio

INDUSTRIAL WASTES FORUM—Renaissance Room
James M. Brown, Leader

Afternoon

RESEARCH FORUM—Twenty-Two Club
George E. Symons, Leader
Biological Purification of Citrus Waste—James B. Lackey
Oxidation of Aromatic Compounds by Activated Sludge—Ross E. McKinney
Fundamental Study of Activated Sludge Bulking—H. Heukelekian and Eugene Weisberg

TECHNICAL PROGRAM COMMENTS

The technical program developed by the Program Committee, under the chairmanship of Rolf Eliassen, is planned to have such wide diversity as to appeal to all Federation members.

To provide more technical papers and increase the time devoted to discussions, the technical sessions of the meeting will extend over four full days, Monday through Thursday. The popular Operators' Forum and the valuable Industrial Wastes Forum will be held concurrently on Thursday morning. To enlarge further the scope of the program, a special forum on research in the sewage and industrial wastes field will be held Thursday afternoon. Fringe-area sanitation will come under discussion in a symposium Wednesday afternoon.

SOCIAL FUNCTIONS

An informal Family Night Entertainment on Monday evening will provide fun for all and a good opportunity to greet old friends and meet new

ones. A Hallowe'en Country Night will prevail in this innovation to Family Night Entertainment. Blue jeans and bandannas for the men and ginghams for the ladies will be the order of informal dress for a gala evening of games and square dancing. Bring your special clothes! Should you prefer costumes, please bring them or rent them. Atlantic City has two costume suppliers. They are: Keating Music Shop, 4005 Pacific Ave.; and Bill Schwab, 1938 Atlantic Ave. The Host Association promises that this will be a gay and colorful event. All are urged to join in the fun by dress and participation!

The Annual Federation Luncheon, to be held Tuesday noon, will be a featured event of the meeting with former Federation Executive Secretary W. H. (Pete) Wisely as speaker. Mr. Wisely, now Executive Secretary, American Society of Civil Engineers, will speak on "The Federation as an International Force."

There will be no programmed entertainment on Tuesday evening, allowing for dining and playing according to individual choice. The Local Host Committee will be prepared to furnish information on the eating and entertainment features of the Atlantic City resort area.

The always popular Annual Dinner and Dance will climax the meeting on Wednesday evening. Featured at this function will be the presentation of the annual Federation awards and honors. There will be music and dancing to an excellent orchestra. Dress will be optional.

A dinner meeting of the Loyal Order of the Boar also is scheduled at the Ambassador Hotel for Tuesday, October 11, at 6 P.M. Arrangements are in charge of W. A. Hardenbergh and J. J. Gilbert; tickets are priced at $5.00.

LADIES' ENTERTAINMENT

Special entertainment for the ladies will be centered around the local sight-seeing attractions of this famous Atlantic Ocean resort. These events will be in addition to those scheduled for Monday and Wednesday evenings, as outlined under "Social Functions."

Monday afternoon will feature relaxation, refreshment, and a chance to meet and greet friends at the Hospitality Hour in the Surf Room of the Ambassador Hotel. Host for this event will be the New Jersey Sewage and Industrial Wastes Association.

On Tuesday morning the ladies will view the Dupont Company's presentation "Your Life and Man-Made Fibres." In the afternoon a tour of the china manufacturing plant at Lenox, Inc., well known makers of fine china, will be an event of exceptional interest. Advance notification at the ladies' desk in the Surf Room is necessary for transportation arrangements.

A luncheon arranged by the Ladies' Committee of the New Jersey Sewage and Industrial Wastes Association at the Marine Grill of Hackney's Famous Sea Food Restaurant on Wednesday will climax the ladies' special functions. Advance notification at the ladies' desk in the Surf Room is necessary for transportation arrangements.

TECHNICAL INSPECTIONS

A programmed inspection trip has not been arranged since the construction of new sewage treatment facilities at Atlantic City will just be commencing. However, those attending the meeting are urged to take advantage of visiting some of the many municipal and industrial waste treatment plants in New Jersey.

By special arrangement, the Host Association has secured permission for convention guests to visit the following plants which can be reached easily from Atlantic City:

Seabrook Farms, Bridgeton, N. J.—frozen food process wastes.

Ciba States Limited, Toms River, N. J.—organic and inorganic chemical wastes.

Information on additional facilities of interest will be available from the Local Host Committee.

EXHIBITS

The display of improved and new equipment and supplies will feature exhibits by members of the Water and Sewage Works Manufacturers' Association. All available exhibit space had been allocated by early August to some manufacturers and suppliers. Viewers of the exhibit will be able not only to see the modern equipment of the sewage and industrial wastes treatment field, but also will be able to get first-hand technical data from informed company representatives.

The following companies have scheduled representation in the exhibit:

ACF Industries, Incorporated
Airkem, Inc.
American City Magazine, The
American Well Works, The
Armco Drainage & Metal Products, Inc.
B-I-F Industries, Inc.
Carter Company, Ralph B.
Chain Belt Company
Chicago Pump Company
Combustion Engineering, Inc.
DeZurik Shower Co.
Dorr-Oliver, Incorporated
Engineering News-Record
Fairbanks, Morse & Co.
Fischer & Porter Company
Flexible, Inc.
Foxboro Company, The
General Electric Company
General Laboratory Supply Company
Hardinge Company
Homestead Valve Manufacturing Co.
Inertol Co., Inc.
Infilco Incorporated
Jeffrey Manufacturing Company, The
Johns-Manville
Komline-Sanderson Engineering Corp.
Lakeside Engineering Corporation
Link-Belt Company
Lock Joint Pipe Company
Mine Safety Appliances Co.
Pacific Flush Tank Co.
Penn Industrial Instruments Division
Pittsburgh Coke & Chemical Company
Preload Company, Inc., The
Public Works Publications
Rockwell Manufacturing Company
Simplex Valve & Meter Company
Vapor Recovery Systems Company, The
Walker Process Equipment, Inc.
Wallace & Tiernan, Inc.
Wastes Engineering
Water & Sewage Works
Wemco Division
Yeomans Brothers Company

REGISTRATION INFORMATION

Atlantic City is on EASTERN DAYLIGHT TIME through October

Registration facilities will be located in the lobby of the Ambassador Hotel from Sunday, October 9 through Thursday, October 13. Early arrivals may register Sunday until 7:00 P.M. On Monday, Tuesday and Wednesday the desk will be open from 9:00 A.M. to 5:00 P.M.

Men's registration at $12.00 will include admission to the technical sessions, the Hallowe'en Country Night Family Entertainment on Monday and the Annual Awards Dinner and Dance on Wednesday. In separate tickets the registration fee (required for admission badge to the technical sessions) is $7.00 and the Wednesday dinner and dance combination is also $5.00. (The division of the $12 Men's Registration fee was incorrectly given in the pre-convention flyer.)

Individual tickets will be sold for the Federation Luncheon on Tuesday at $3.50.

Ladies' registration at $10.00 includes the Monday evening entertainment, the Wednesday evening dinner and dance, and all special events in the ladies' program, including the luncheon on Wednesday.

Early registration—before 7 P.M. on Sunday—will avoid the rush on Monday morning and also permit a leisurely visit of the manufacturers' exhibit.

HOTEL ARRANGEMENTS

A liberal allocation of rooms has been made by the Ambassador Hotel for assignment to Federation members and guests. Reservations should be made early, however, to assure accommodations in the headquarters hotel. When all available rooms in the Ambassador are committed, reservation requests will be referred to other nearby first-class hotels.

Requests for reservations may be made on the forms provided with the advance notice of the meeting sent in July to all Journal subscribers, or directly to the Ambassador Hotel, Atlantic City, N. J.

LOCAL ARRANGEMENTS COMMITTEE

The Local Arrangements Committee, under the chairmanship of Sol Seid, Supervisor, Department of Public Works, New Brunswick, N. J., is composed of the chairmen of the following sub-committees:

Registration Committee: Andrew Palmer, Chairman; W. S. Applegate, C. Molitor, C. B. McMannamin, W. H. Higgins, M. S. Kachorsky, R. J. Budrick, A. Scocco, and W. J. Fairbrother.

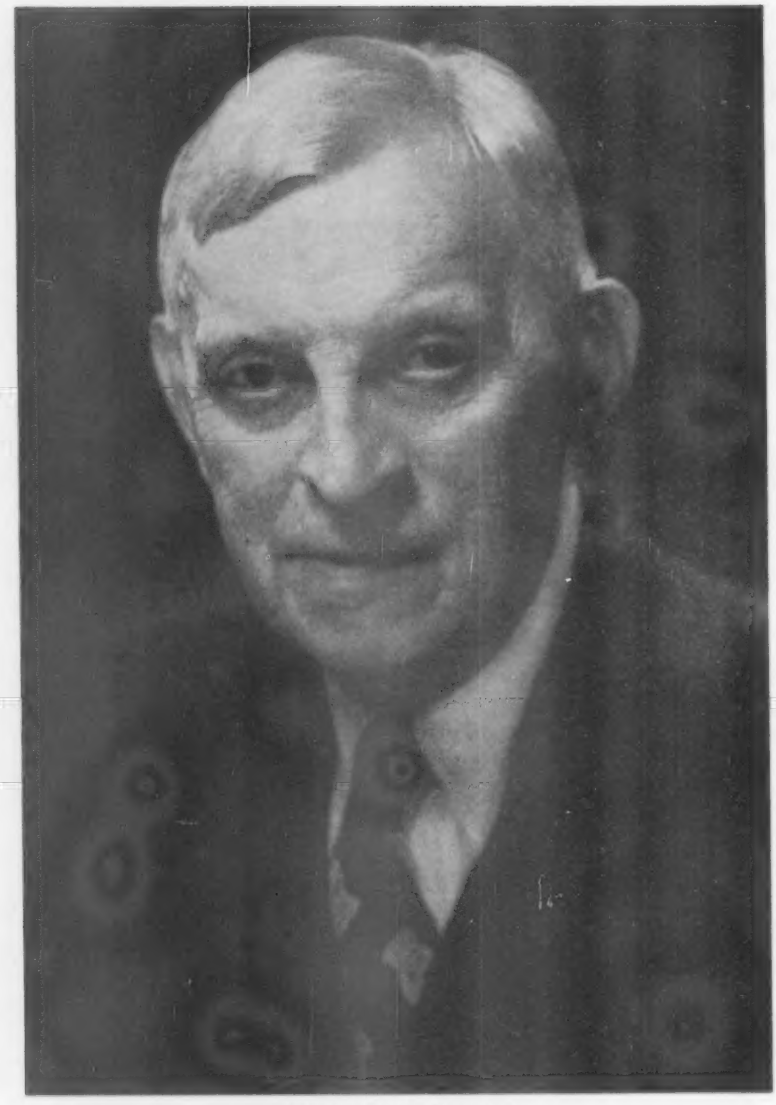
Hotel Arrangements Committee: H. C. Greenfield, Chairman; R. B. Mowry, W. Gross, M. Brunstein and A. Leahey.

Finance Committee: P. N. Daniels, Chairman; C. Ellis, C. D. Morelli and L. Morrill.

Entertainment Committee: J. Horgan, Chairman; J. Stewart, D. Gallagher and C. Ressen.

Ladies Entertainment Committee: Mrs. A. Clark, Chairman; Mrs. S. Seid, co-chairman; Mrs. M. Brunstein, co-chairman; Mrs. M. Kachorsky, Mrs. H. Van Der Vliet, Mrs. J. Horgan, Mrs. L. Fontenelli, Mrs. F. V. Orden, Mrs. H. P. Croft, Mrs. P. N. Daniels, Mrs. R. Mowry, Mrs. J. Collom, Mrs. H. C. Greenfield, Mrs. A. H. Fletcher, Mrs. L. F. Frazza, Mrs. R. Shaw, Mrs. L. Klockner, Mrs. A. Palmer and Mrs. J. Hood.

Local Host Committee: J. LeChard, Chairman; G. A. Scheiter, E. Steelman, J. Moncrieff, G. Fieldhouse and A. Macri.



Charles Alvin Emerson

CHARLES ALVIN EMERSON (1882–1955)

In Memoriam

It is with extreme regret that we note the passing of Charles Alvin Emerson, the first president of the Federation. His death came after an illness of one month in East Orange, New Jersey, on August 24, 1955.

To affiliates of the Federation of Sewage and Industrial Wastes Associations, he was thought of as "Mr. Federation." This title was one he richly deserved because of his years of unrelenting devotion to the problems and activities of our organization. He was not only a most active member of the Committee of One Hundred which wrought the original union of member associations in 1928 but he served as President until 1941.

Mr. Emerson, or "Charlie," as he preferred to be called, was the first one to be named an Honorary Member of the Federation in 1941. In further recognition of his great Federation service, the Board of Control established in 1943 the Charles Alvin Emerson Award to be given annually for "outstanding service in the sewerage and sewage treatment works field as related particularly to the problems and activities of the Federation in such terms as the stimulation of membership, improving standards of operational accomplishments, and fostering fundamental research." He took great pride and satisfaction in making the annual presentation of this award personally. His own life is a true exemplification of the honor which bears his name.

Born in Beloit, Wisconsin, June 10, 1882, he graduated from Beloit College in 1903 cum laude, and from Massachusetts Institute of Technology in 1905. Beloit College recognized his professional attainments by conferring the Honorary Degree of Doctor of Philosophy upon him in 1953. His early work was on water and sewage works projects at Columbus, Ohio and later Baltimore, Md. where he was assistant and then division engineer on the design and supervision of construction of the outfall sewer and treatment plant. In 1911 he joined the Pennsylvania State Department of Health as Principal Assistant Engineer in charge of Design and Construction and three years later he became Chief Engineer in charge of water and sewage improvement throughout the Commonwealth. He developed some of the first standards for limits of permissible stream pollution in the state of Pennsylvania.

In 1923 he entered private engineering practice with the firm of Fuller and McClintock and later became a member of the firm of Gascoigne and Associates. In August, 1940 and until his retirement in 1955, he was partner in the firm of Havens and Emerson, New York and Cleveland consulting engineers.

As a contributing editor, he assisted in the preparation of three references and textbooks entitled "Sewage Disposal," "Solving Sewage Treatment Problems" and "Manual of Water Works Practice." He was the author of many papers on problems in the field of sanitary and public health engineering presented before national engineering societies and published in technical journals.

A life member of many professional societies in the civil engineering field he was a registered professional engineer in several states. Mr. Emerson was well known for his guidance of Federation activities since his retirement from its chairmanship in 1941 and has been a familiar figure at Federation Board meetings. He saw the Federation grow to include 38 affiliated associations with an aggregate membership of 6500.

The loss of Charlie Emerson is one that will be deeply felt by all of those with a strong interest in the Federation. The unblemished record of his life can but offer a great challenge to those who inherit his work and particularly to those who have received the Federation Award which bears his name.

R.E.F.

Reviews and Abstracts*

Investigation and Application of the Electrochemical Determination of Dissolved Oxygen for the Examination of Waters. By W. Ohle. *Vom Wasser*, 19, 99 (1952).

D.O. is measured by a galvanic cell with gold and zinc electrodes incorporated in an oxygen plummet. Factors affecting the proportionality of D.O. and diffusion current are the electrodes, total electrolyte concentration, pH, temperature, and flow rate of water. To offset diffusion current variations due to electrolyte concentrations between 40 and 14,000 p.p.m., a variable resistance ammeter was connected to the plummet. pH variations between 3 and 11 and hardness up to 120 p.p.m. $CaCO_3$ have no effect. In a water containing 209 p.p.m. $CaCO_3$ hardness, there was a steady decrease of the diffusion current with time due to scaling. A curve shows the percentage variation of current with temperature between 0° and 25°C. The flow rate of the water past the electrodes must be such that the cathodic diffusion zone is constantly renewed. This can be achieved by shaking the plummet with the cable in shallower waters. In very deep seas a motor-driven stirrer near the electrodes would be necessary. For absolute D.O. measurement, a standard D.O. *vs.* current curve should be constructed for different kinds of waters. D.O. profiles of four different lakes show about ±5 per cent deviations from the Winkler D.O. The use of the plummet makes possible extensive horizontal and vertical D.O. profile studies of rivers, estuaries and lakes.

Peter K. Mueller

Electrochemical Determination of Dissolved Oxygen of Surface Waters. By F. Todt and H. G. Todt. *Vom Wasser*, 20, 72 (1953).

The diffusion current produced in a galvanic cell of gold (cathode) and zinc (anode) electrodes which are dipped in an electrolyte containing D.O., is proportional to D.O. concentration. The investigations and electrochemical principles basic to the development of such a device suitable for measuring D.O. in surface waters are thoroughly described. Linear relationships between D.O. concentration and diffusion current exist for 0.20- to 0.02-sq.cm. cathodes when the electrolyte concentration is 200 p.p.m. NaCl or more. With lower electrolyte concentration and the same cathode the current change per p.p.m. D.O. decreases at the higher D.O. levels. With increasing size of cathode the electrolyte concentration must become larger to maintain linear proportionality. Carbonate hardness of surface waters produces scaling on the cathode, thus reducing the current in time. Microscopically amorphous surfaces and increasing size of cathode reduce the effect of scaling. A specially hammered, gold, 0.20-sq.cm. electrode successfully measured D.O. in waters containing up to 190 p.p.m. $CaCO_3$ hardness. A mercury cathode permitted measurements up to 350 p.p.m. hardness. After a series of measurements, the electrodes must be rinsed with 1N acetic acid. A portable oxygen plummet, designed for direct determination of D.O. in lakes and rivers from a boat, consists of a weighted plexiglass cell in which the electrodes are suspended by a long cable from the ammeter. A stationary continuous recording device in which the water passes through an ion exchanger prior to flow past the electrodes is also described. Peter K. Mueller

Investigations on Chemical Precipitation at Salford. By T. Stones. *Jour. Inst. Sew. Purif.* (Brit.), 117 (1952).

Precipitation of the Salford sewage with alum under various conditions has been explored. All experiments were made in duplicate, one on the normal industrial sewage as received at the Salford treatment

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N.W., Washington 16, D. C.

works and, for comparison, the other on samples of purely domestic sewage.

Optimum precipitation appears to occur around pH 5.0, although the settled liquor resulting from precipitation under such conditions would not be amenable to subsequent biological treatment without prior neutralization. Precipitation with alum under acid conditions led to the deduction that the active precipitating agent is aluminum hydroxide formed by hydrolysis and not aluminum ions.

At normal pH values, alum is largely hydrolysed so that under these conditions addition of lime in stoichiometric proportions to ensure formation of aluminum hydroxide is not only unnecessary, but also may be a definite disadvantage.

Mechanical flocculation not only produces a more rapidly settling precipitate and well-clarified supernatant liquor, but also leads to more effective precipitation with alum.

The degree of treatment attainable by precipitation with alum is not simply a function of the dosage of precipitant employed, but depends also on the pH of the sewage and whether precipitation has been supplemented by flocculation.

AUTHOR

Treatment of Gas Liquor on Percolating Filters. By H. R. GAILLARD. *Surveyor*, 113, 1114 (1954).

Mixtures of domestic sewage with crude and spent gas works liquors were treated on experimental trickling filters 3 ft. in diameter and 6 ft. deep.

With sewage alone, as the filter loading was increased from 0.09 to 0.32 lb. O.A. per cu.yd. per day, the effluent B.O.D. rose smoothly from 11.5 to 22.5 p.p.m. When spent liquor was added, the results fell on the same curve. However, when crude liquor was present, the effluent B.O.D. for a given filter loading was increased by approximately 50 per cent. To obtain a given effluent B.O.D., only about one-half as much O.A. load could be applied when crude liquor was present as when only spent liquor, or no liquor, was added.

The effects of the liquors upon nitrification were:

1. A steady reduction of effluent nitrate concentration as loads increased from 0.1 to 0.3 lb. O.A. per cu.yd. per day.

2. 10 p.p.m. more effluent nitrate with spent liquor added than with none.

3. An adverse effect of crude liquor, even in small amounts.

4. Increased effluent nitrite resulting from the addition of spent liquor, and a greater increase when crude liquor was added to the sewage.

5. Ammonia removal inversely proportional to the filter loading. M. C. RAND

A Study of Some Factors Affecting the Bottom Fauna of a Portion of the San Francisco Bay Estuary. By FRANCIS P. FILICE. *Wasmann Jour. Biol.*, 12, 3, 257 (1954).

A survey of the invertebrate bottom fauna of San Francisco Bay between Antioch Bridge and Point San Pablo was made to study the effects on the fauna of pH, salinity, oxygen content, type of substrate, and presence or absence of domestic and industrial wastes.

Although pH is greater closest to the fresh-water source, decreasing to that of sea water as one goes seaward, there is no demonstrable correlation between pH and the presence of wastes. There has been no appreciable change in pH of this part of the estuary since 1928.

The oxygen content of the surface waters is usually below saturation. Depressed oxygen values seem to have no correlation with the presence of wastes or any effect on the fauna.

At estuary locations where industrial wastes are located the depressive effect on the volume of fauna is obvious, but as dilution becomes operative the effect decreases. Sewage outlets do not exert as great an influence as industrial outfalls, the increased organic content actually increasing the volume of fauna outside the zone of greatest toxicity. H. P. O.

A Respirometer for the Study of the Oxygen Demand of Polluted Water and Sewage. By A. B. WHEATLAND AND R. LLOYD. *Lab. Practice*, 4, 1, 6 (1955).

A new type of respirometer suitable for studies of the oxygen demand of polluted water and sewage is described. In the apparatus the volume is kept almost constant and the oxygen consumed is measured by the change in pressure. A large volume of sample may be used. The necessary

rate of solution of oxygen in the sample is maintained by continuous stirring with a magnetic stirrer. H. P. O.

Automatic pH Control in Effluent Treatment at a Wool Mill. By R. Wilkinson. Reprint from *Textile Mfr.* (Brit.) (Jan., 1953).

Wool mill waste flow averaging 20,000 g.p.h. (Imp.) during a 10-hr. working day is subjected to acid cracking for recovery of wool grease. Previously, alum and lime flocculation plus settling was carried out by continuous feeding. Automatic pH control equipment now varies the lime slurry addition (about 800 p.p.m. as $Ca(OH)_2$) to meet process demands. The improvement has exhibited marked benefits in effluent B.O.D., oxygen absorbed and suspended solids. H. P. O.

The Toxicity of Potassium Cyanide to Trout. By D. W. M. Herbert and J. C. Merkens. *Jour. Exper. Biol.*, 29, 4, 632 (1952).

An apparatus is described in which 50 yearling rainbow trout can be tested in a stream of water at constant temperature and constant poison concentration. Small yearling rainbows tend to be more resistant to cyanide than larger fish of the same age. The distribution of survival time logarithms is sufficiently close to normal to justify application of standard statistical techniques. The resistance of individual fish to cyanide is mainly determined by inherent properties which persist for at least three weeks.

At 17.5° C. in the range 2.5 to 0.07 p.p.m. CN mean log survival time decreases linearly with log concentration, the variance of log survival time is approximately constant, and distribution of log survival time is approximately normal. At higher concentrations these statements do not hold true. H. P. O.

Microbiological Changes in Carbohydrate Media: Effect of Aeration on pH Value and on Oxidation and Assimilation. By L. A. Allen, A. H. Cooper and J. Naomi Rose. *Jour. Appl. Bact.*, 17, 1, 57 (1954).

Chemical changes resulting from microbial growth in a simple medium containing glucose as the only source of carbon, and ammonia as the only source of nitrogen, depended not only on the concentration of nutrient materials and the air supply rate, but also on the shape and size of the container, the depth of liquid and the method of aeration. If the pH value had not fallen below about 3.0 by the time all the glucose was destroyed, continued aeration raised the pH substantially, due to oxidation to CO_2 of organic acids formed in the earlier stages.

Initial growth in a simple medium was suppressed not only by aeration of a pure culture with a current of CO_2-free air, but also by violent aeration of a mixed culture with air with normal CO_2 content.

Changes occurring in a complex organic medium (a sterile extract of red beet) were similar in character to those observed in the simple medium, but were much less affected by irregularities in growth. H. P. O.

Treatment and Disposal of Waste Waters from Dairies. By B. A. Southgate. *Dairy Sci. Abs.*, 16, 6, 428 (1954).

This article is a general review and discussion of dairy waste disposal and treatment by irrigation, lagooning, digestion, chemical treatment, trickling filters, activated sludge and aeration. Comparatively little advance seems to have been made in the technique of treating milk wastes during the past 15 years. Aerated storage tanks are well established in America, but both U. S. and British opinion seems still to favor biological filtration over the activated sludge process. Septic tanks are still unsatisfactory. Fermentation under controlled conditions may be an economic method of treating for particularly strong wastes. H. P. O.

Factors Affecting the Growth of Some Fungi Associated with Sewage Purification. By H. A. Painter. *Jour. Gen. Microbiol.*, 10, 1, 177 (1954).

A study of various aspects of the nutrition of four fungi which commonly inhabit trickling filters showed that *Sepedonium* n. sp., a predominating fungus, required organic sources of N while *Fusarium aqueductum*, *Geotrichum* sp. and *Trichosporon cutaneum* were able to utilize ammonium salts. *F. aqueductum* was also able to utilize nitrate. *Geotrichum* sp. and *F. aqueductum* needed no external supply of vitamins, *T. cutaneum* required thiamine

and *Sepedonium* sp. required thiamine and biotin for optimum growth. The pH range for optimum growth was narrow (pH 7 to 8.5) for *Sepedonium* sp. while the ranges for the other fungi were much wider (pH 3–4 to 9).

Zn, Ca, Mn and probably Fe and Cu were required by *Sepedonium* sp., which was the only one of the four fungi inhibited by concentrations of Zn above the optimum in media partially deficient in other elements. Mn, Fe on Cu when added with Zn counteracted the inhibitory action, while Ca increased it. H. P. O.

Further Experimental Work on Gas Liquor Treatment. By A. J. Clifford and J. T. Rees. *Jour. Inst. Sew. Purif.*, 37 (1953).

A control filter received 0.43 per cent by volume of gas liquor pretreated by concentration and dephenolation. The second filter was dosed at 0.69 per cent. The added load adversely affected the effluent quality from 100 g.p.d. (Imp.) per cu.yd. application of sewage. By recirculation of effluent to the filter the volume of gas liquor applied could be doubled. H. P. O.

The Influence of Dissolved Oxygen Concentration on the Toxicity of Potassium Cyanide to Rainbow Trout. By Kathleen M. Downing. *Jour. Exp. Biol.*, 31, 2, 161 (1954).

Survival times of rainbow trout in concentrations of KCN in the range 0.105 to 0.155 p.p.m. CN increased with increase in D.O. concentration between 10 and 100 per cent of air saturation value, the effect being most marked with the lowest concentration of cyanide. The rate of increase of survival time with increasing concentration of oxygen did not appear to fall off as air saturation value was approached. The distribution of survival times which had median values of 3.3 min. or less were approximately normal; those with median values of 13.0 min. or more were approximately log-normal. H. P. O.

Pollution of the Mississippi River Near New Orleans. By Frank W. Macdonald. *Proc. ASCE*, 80, Sep. No. 552 (Nov., 1954).

This report of a study to determine the degree of pollution of the Mississippi River on arrival at New Orleans and as a result of discharge of the city's wastes reviews the bacteriological records from 1934 on. Results of correlating these records with stream flow variation are compared with water quality standards used in various sections to determine (a) suitability of the river water as a source of raw-water supply and (b) suitability of present standards as a means of evaluating raw-water supply quality.

Data presented demonstrate that monthly averages of M.P.N. constitute a poor index of stream pollution. One or two extremely high daily values during a month distort the averages to give an untrue representation of the general conditions for the period. The monthly median or geometrical mean is suggested as a better index. Sampling practice is also discussed. The M.P.N. varied with stream flow, the greater values occurring generally during minimum flows. H. P. O.

A Continuous Recorder for Dissolved Oxygen in Water. By R. Briggs, G. Knowles and L. F. Scragg. *Analyst*, 79, 945, 744 (Dec., 1954); also *Water and San. Eng.*, 5, 1, 24 (1954).

Winkler's method for oxygen in water has been mechanized and adapted to automatic operation. The optical densities of the iodine solutions produced are measured by a photocell, the current from which is amplified, rectified and automatically recorded. Inherent absorption of the samples and reagents is recorded after addition of sodium sulfite to remove the iodine color. The oxygen content is then calculated from the difference between the two readings. In laboratory tests on water containing 2 to 8 p.p.m. of oxygen by weight the maximum error was 0.05 p.p.m. Authors

Treatment of Waste Waters from Chemical Industries. By R. Wilkinson. Reprint from *Chem. Prod.* (Brit.) (Mar., 1953).

This is a general review of the methods of dealing with chemical waste disposal. The general methods of treatment and disposal of waste waters are described, including in-plant process modifications to make the wastes less difficult to treat. Illustrative examples complete the presentation. H. P. O.

Recovery of Phenolics from Waste Effluents. By Radcliffe G. Edmonds and George F. Jenkins. *Chem. Eng. Prog.*, 50, 3, 111 (1954).

The paper describes an installation for recovery of phenolics from the process effluents of a coal-hydrogenation plant located at Institute, W. Va., together with operating results of the treatment plant for the further waste discharges.

The recovery plant includes oil separation; stripping of the water phase to remove ammonia, H_2S, and CO_2; scrubbing with an isopropyl ether; and restripping of the solvent. The ether is then recovered, the phenolic material being combined with the plant oil streams. Water effluent from the system is settled in open basins before discharge to the Kanawha River.

A modified ultraviolet absorption method, using a base-line technique at 290 mμ, has proved reproducible and convenient for phenolic contents above 0.0001 per cent. Comparison with standard methods of phenol analysis has disclosed the presence of a class of phenolic compounds not previously indicated. This material is much less volatile and far more soluble in water than phenol or cresols. Therefore, the tolerance limits must be established for these new contaminants. H. P. O.

Removal of Radioactive Substances from Water by Biological Treatment Processes. By G. E. Eden, G. H. J. Elkins and G. A. Truesdale. *Atomics*, 5 (May, 1954).

On slow sand filters, Ru^{106} appeared in the effluent within 2 hr. of the first application and rose to about 85 per cent of the concentration in the unfiltered water. When uncontaminated water was subsequently run, activity of the effluent fell rapidly although contamination was still detectable after 14 days. Although strontium was effectively removed for a few hours, the effluent activity reached 30 per cent of that in the unfiltered water in 1 day, 70 per cent in 2 days, and 95 per cent after 7 days. Uncontaminated water effluent remained seriously contaminated for several days thereafter. I^{131} behaved similarly, except that the effluent activity tended to a limiting value of 50 per cent. Pu was fairly effectively removed, the effluent value tending to about 10 per cent. Results from the filters are definitely biological, rather than just physical adsorption on the apparatus. The process affords little protection to the consumer of drinking water against contamination by Ru^{106}, Sr^{90} and I^{131}.

In the activated sludge process, the optimum pH value for removal of radioactive contaminants was quite different for different isotopes. Cerium was the most efficiently removed element; caesium or ruthenium the least. About 96 per cent Pu was removed in 24 hr., even at comparatively high concentrations. Despite this, the activated sludge process is not likely to compete in reliability or efficiency with chemical methods. However, biological treatment of effluents otherwise requiring such treatment to remove organic matter would in many cases result in a useful reduction in activity. Biological treatment might also find application in treatment of effluents not amenable to treatment by purely chemical methods, such as those containing organic complexes of radioisotopes. H. P. O.

Effect of Certain Antibiotics on Acticated Sludge. By S. C. Pillai, A. V. S. Prabhakara Rao and G. J. Mohan Rao. *Science and Culture* (India), **18**, 545 (1953).

Samples of activated sludge were treated with various concentrations of aureomycin hydrochloride, dehydro-streptomycin-sulfate and sodium salts of penicillin. Even 4 p.p.m. of aureomycin adversely affected the clarifying action of the sludge. The species of *Epistylis* that are most important in clarification of sewage were found considerably inactivated. The bacterial content was not appreciably affected, but nitrate and nitrite N increased. The clarifying action of sewage and protozoal activity decreased in inverse rate to the strength of the aureomycin. With 10 p.p.m. and more of aureomycin, the protozoa were affected and when treated samples were washed and added to heat sterilized sewage, aerated for 24 hr., and examined, they showed dead protozoa.

Further experiments with *Vorticella* sp. showed that more than 2 p.p.m. of aureomycin inhibited, but up to 4 p.p.m. they could be developed into activity on washing. Similar tests with penicillin and streptomycin showed much the same pattern. H. P. O.

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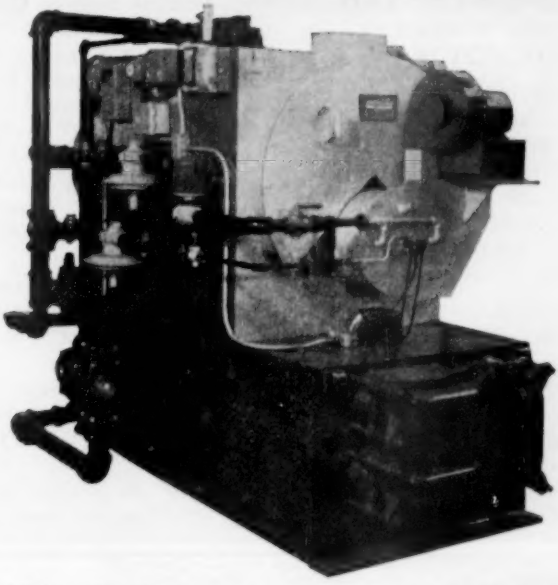

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Proceedings of Member Associations

ARIZONA SEWAGE AND WATER WORKS ASSOCIATION

The 1955 Annual Meeting of the Arizona Sewage and Water Works Association was held at the San Marcos Hotel, Chandler, Ariz., April 14–16, 1955. Registration of water and sewage works personnel totaled 157.

Among the interesting papers presented were the following:

"New Developments in Sewage Works," by Dr. J. A. Montgomery, President, Lakeside Engineering Corp., Chicago, Ill.

"Excavation and Backfill," featuring the viewpoints of the owners and contractors respectively by George T. Grove, Director, Tucson Public Works and John T. Young, Executive Secretary, Central Arizona Concrete Assn.

"Adult Education," by John C. Park, Dean, College of Engineering, University of Arizona, Tucson.

"Lightning Protection for Water and Sewage Works," by Earl S. Prud'homme, General Electric Co.

"Proper Liability Insurance Coverage for Utilities," featuring the insurance company and utilities management viewpoints respectively by W. J. McKinnon, American Indemnity Co., Los Angeles, Calif. and Ralph F. Thompson, Arizona Public Service, Phoenix.

"New Zealand Sewage Survey," by A. M. Rawn, General Manager, County Sanitation District of Los Angeles County, Calif.

"Utility Re-location and Altera-

(*Continued on page 388a*)

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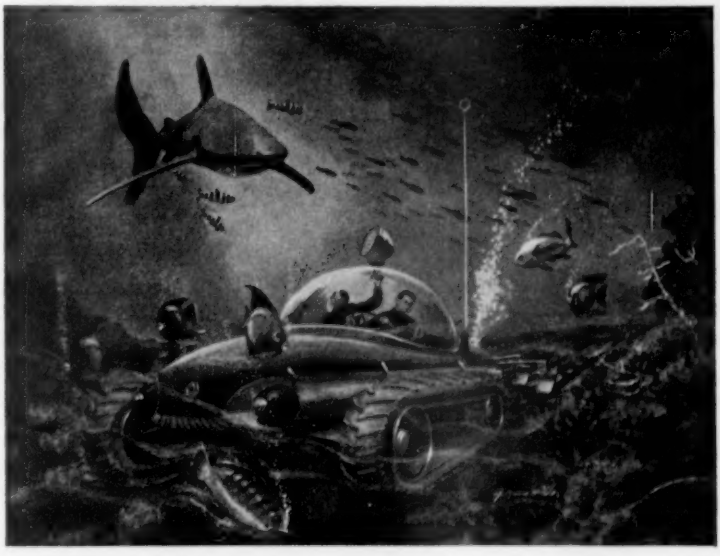

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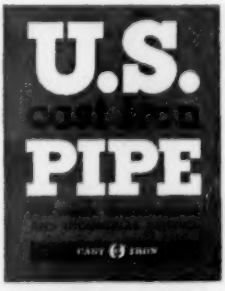

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tions," by Frank C. Amsbary, Jr., Vice-President, American Water Works Assn. and John A. Carollo, Partner, Headman, Ferguson and Carollo, Engineers, Phoenix.

An operator's round-up for sewage and water plant operators featured discussions on schooling of operators, and collection, distribution and plant problems.

M. V. Ellis was presented with the Federation's Arthur Sidney Bedell Award by Federation Vice-President George Martin.

At the luncheon and business meeting the following officers were elected to serve for 1955–56:

President: G. Ted Rekerdre, Tucson
1st Vice-President: M. V. Ellis, Phoenix.
2nd Vice-President: Thomas Nesbitt, Tucson.
FSIWA Director: John A. Carollo, Phoenix.
Secretary-Treasurer: Quentin M. Mees, Tucson.

The Association voted to establish an annual scholarship of $100 for a junior student registered in the Sanitary Option of Civil Engineering at the University of Arizona.

QUENTIN MEES,
Secretary-Treasurer

LOUISIANA CONFERENCE ON WATER SUPPLY AND SEWERAGE

The 1955 Annual Meeting of the Louisiana Conference on Water Supply and Sewerage was held in conjunction with the 18th Annual Operator's Short Course at Louisiana State University, Baton Rouge, La., March 16–18, 1955.

In addition to the usual short course lectures and laboratory demonstra-

(*Continued on page 390a*)

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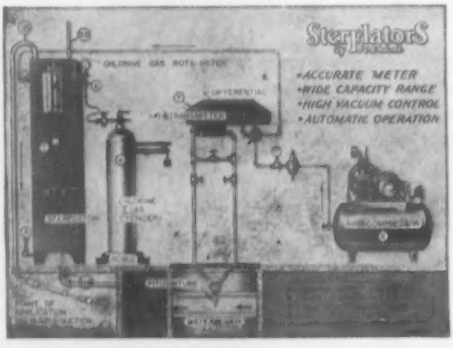

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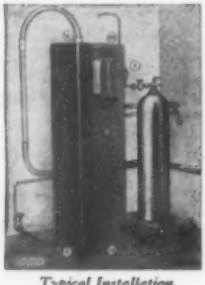
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tions, the following papers of interest to sewage works personnel were presented:

"Sewer Maintenance," by L. T. Harper, City Engineer, Monroe.

"Control of Frothing in Aeration Tanks," by Robert Arthur, Chicago Pump Co., Chicago, Ill., and J. B. Baudoin, Water and Sewerage Dept., Lafayette, La.

"Sewage Lift Station Maintenance," by J. L. Love, Superintendent, Water and Sewerage Dept., Lafayette.

"Sewerage Ordinances," by A. J. Szabo, Regional Engineer, Louisiana State Board of Health.

"Effect of Industrial Waste on Sewage Treatment," by J. B. Baudoin, Water and Sewerage Dept., Lafayette, and William Robert, Operator, Sewage Treatment Plant, Opelousas.

Officers elected were:

Chairman: R. L. Lawrence, Alexandria.

Vice-Chairman: L. B. Bankston, Baton Rouge.

FSIWA Director: J. L. Love, Lafayette.

Secretary-Treasurer: G. H. West, Lake Charles.

GEORGE H. WEST,
Secretary-Treasurer

CALIFORNIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 27th Annual Convention of the California Sewage and Industrial Wastes Association was held at the Mission Inn, Riverside, Calif., April 27–30, 1955. A record registration of almost 500 marked the continued growth of the Association:

Forums and discussion breakfasts were featured. At the Operators' Breakfast committee reports were pre-

(*Continued on page 392a*)

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sented on operator certification, job descriptions, operator schools and local sections. At the Sewer Maintenance Breakfast the following papers were presented:

"Starting a Sewer Maintenance Program," by O. L. Dickinson, Field Engineer, Clay Pipe Institute, Los Angeles.

"Personal Liability of Public Employees Engaged in a 'Governmental' Function," by John C. Nimocks, Deputy City Attorney, Long Beach.

"Saddling Problems," by J. A. McCollum, District Foreman, Sewer Maintenance Division, Los Angeles.

"House Connections—Whose Responsibility?" by Cedric Webster, Superintendent, Menlo Park Sanitary District, Menlo Park.

The forum on operation and maintenance featured the following papers:

"Overloaded Sewage Treatment Plants and What the Operator Can Do About it," by Harry A. Tow, Director of Public Works, Santa Barbara.

"How Do You Look for Corrosion?" by Edwin R. Stowell, Senior Sanitary Engineer, Division of Architecture, State of California.

"Pumping Problems," by C. W. Lindeman, Peerless Pump Division, Food Machinery and Chemical Corp., Los Angeles.

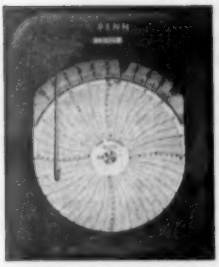
"The Administrator's and Operator's Responsibility to Each Other," by Eric V. Quartly, Superintendent, Sewage Treatment Division, San Diego.

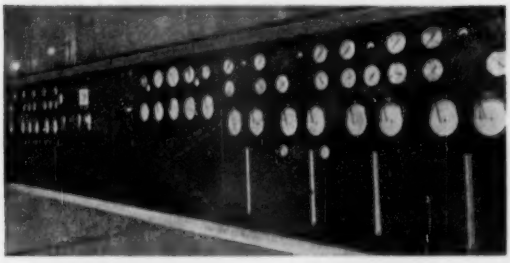
At the industrial wastes forum the papers presented were:

"Waste Water Reutilization and Disposal at Lever Brothers Co.," by R. E. Sessler, Plant Engineer, Lever Brothers Co., Los Angeles.

"Disposal of Wastes From California Oil Fields," by Hubert Ferry,

(*Continued on page 394a*)





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"Committee Report, Municipal and County Ordinances Regulating the Disposal of Industrial Wastes to Sewers and Spreading Grounds," by John H. Ashley, Industrial Wastes Engineer, City of Los Angeles.

The general sessions featured the following papers:

"The Use of Sewer Service Revenue for Financing Sewerage Projects," by Richard M. Bartle and Edwin A. Wells, Jr., Stone and Youngberg, San Francisco.

"Subdivisions—Sewers or Septic Tanks?" by Lloyd O. Leslie and Arnold Punshon, Sanitary Engineers, Federal Housing Administration.

"Philosophy of Water Pollution Control in California," by A. M. Rawn, and Vinton W. Bacon, respectively, Chairman and Executive Officer, California State Water Pollution Control Board.

"Oceanographic Factors in Sewage Disposal," by D. L. Inman and J. F. T. Saur, respectively, Assistant Professor of Marine Geology, Scripps Institution of Oceanography, University of California and Oceanographer, Naval Electronics Laboratory, San Diego.

"A Critical Review of the Bacteriological Standards for Bathing Waters," by William F. Garber, Laboratory Director, Sewage Treatment Division, City of Los Angeles.

"Survival of Coliform Organisms in Pacific Ocean Coastal Waters," by Isadore Nusbaum and Richard M. Garver, respectively, Engineer, Regional Water Pollution Control Board No. 9, San Diego and Lt., U.S.N., Navy Preventative Medicine Unit No. 5, San Diego.

"Diffusion of Effluent Discharged to Puget Sound," by Richard G. Tyler, Professor Emeritus, University of Washington.

At the Annual Business Meeting discussion centered around a more suitable name for the Association. Approval was given to a contest to solicit suggestions for a new name. A pocket-sized safety manual for operating personnel was scheduled for publication late in 1955. Officers elected for 1955–56 are:

President: Herbert B. Foster, Jr., Berkeley.
1st Vice-President: Eric V. Quartly, San Diego.
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..... copies * MOP No. 4, "Chlorination of Sewage and Industrial Wastes" (1951)
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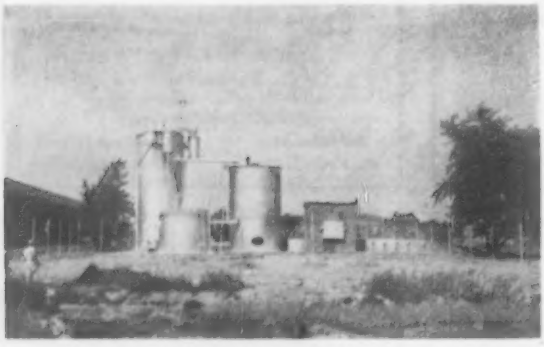

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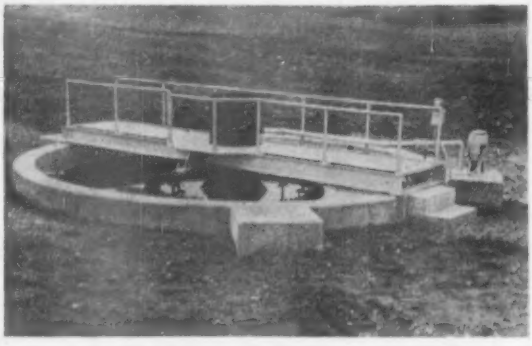

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INDEX TO ADVERTISERS

	Page
American Brass Company	364a
A C F Industries, Incorporated (Valve Division)	367a
American Cast Iron Pipe Company	381a
American Well Works	374a
Armco Drainage and Metal Products, Incorporated	358a, 359a
Bailey Meter Company	389a
Builders-Providence, Incorporated (B-I-F Industries, Inc.)	347a
Carborundum Company, The	378a
Cast Iron Pipe Research Association	354a, 355a
Chain Belt Company	356a, 357a
Chapman Valve Manufacturing Company	370a
Chicago Bridge and Iron Company	366a
Chicago Pump Company	Inside front cover, 345a
Clow, James B., and Sons (Iowa Valve)	373a
Combustion Engineering, Incorporated (Raymond Division)	368a
DeZurik Shower Company	390a
Dorr-Oliver Incorporated	Inside back cover, 384a
Everson Manufacturing Corporation	388a
Fischer and Porter Company	380a
Flexible Sales Corporation	406a
Graver Water Conditioning Company	361a
Hardinge Company, Incorporated	360a
Infilco Incorporated	395a
Jeffrey Manufacturing Company	377a
Johns-Manville Corporation	371a
Komline-Sanderson Engineering Corporation	376a
Lakeside Engineering Corporation	404a
Link-Belt Company	369a
Lock Joint Pipe Company	379a
Morse Brothers Machinery Company	391a
National Clay Pipe Manufacturers, Incorporated	362a
Nichols Engineering and Research Corporation	372a
Pacific Flush Tank Company	382a, 397a
Penn Industrial Instruments	393a
Portland Cement Association	353a
Process Engineers, Incorporated	365a
Simplex Valve and Meter Company	349a
Snow Gates and Valves	386a
Tnemec Company, Incorporated	392a
United States Pipe and Foundry Company	387a
Vapor Recovery Systems Company	375a
Walker Process Equipment, Incorporated	385a
Wallace and Tiernan Company, Incorporated	Back cover
Worthington Corporation (Public Works Division)	363a
Yeomans Brothers Company	351a, 352a
Zimmer and Francescon	394a

DIRECTORY OF ENGINEERS, pp. 398a–403a

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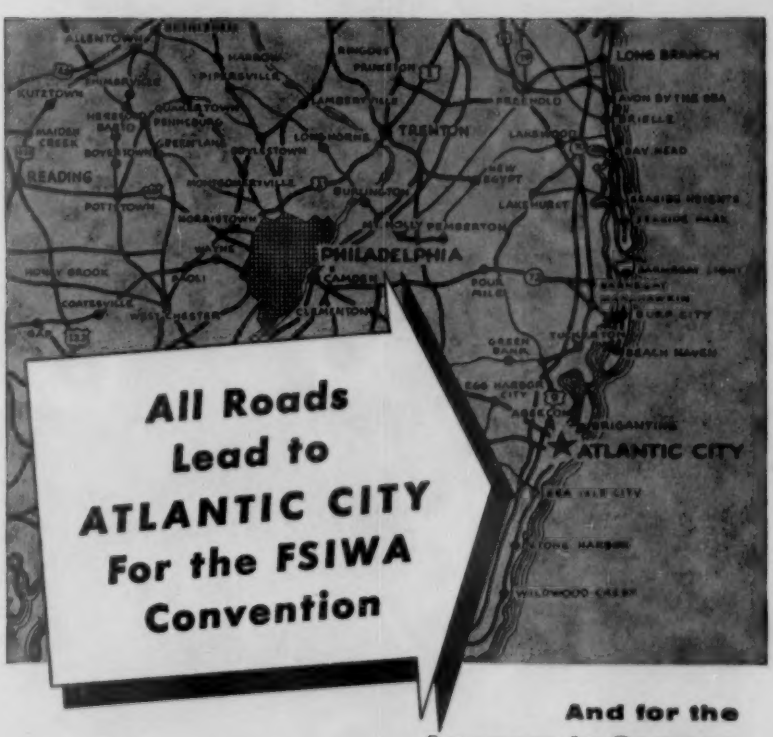

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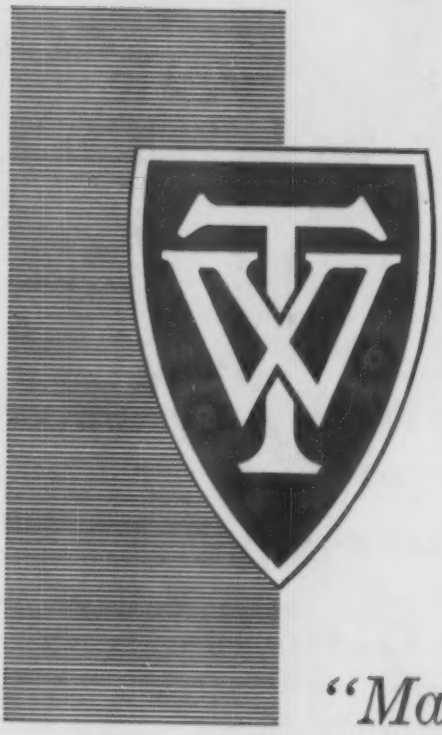

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